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CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Voting members: Any person who has a baccalaureate degree and holds an official position in any agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, a Vice-President, a Secretary-Treasurer, and sectional chairmen to represent the subject-matter sections of the Society.

ARTICLE VI

The Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS*

Section 1—*Duties of Officers:* The President shall preside at business meetings and general sessions of the society, deliver an address at the regular annual meeting, and serve ex officio as a member of the executive committee.

The Vice-President shall preside at business meetings and general sessions of the Society in the absence of the President and serve ex officio as a member of the executive committee.

The Sectional Chairmen shall preside at sectional meetings and serve ex officio as members of the executive committee.

The Secretary-Treasurer shall keep the records of the Society; edit, publish, and distribute the Proceedings and other publications; mail to members a call for papers for the annual meeting at least 30 days prior to closing date for acceptance of papers, and at least 3 months prior to the annual meeting shall request of members suggestions regarding nominations, matters of policy and general welfare of the Society; serve ex officio as a member of the executive and program committees; collect dues from members; and conduct the financial affairs of the Society with the aid and advice of the chairman of the executive committee.

Section 2—*Executive Committee:* There shall be an executive committee consisting of the retiring President, who shall be chairman, the President, the Vice-President, the Sectional Chairmen, the chairmen of regional groups, the Secretary-Treasurer, and two members elected at large for terms of two years each, retiring in alternate years. This committee shall act for the Society in the interim between annual meetings; shall fix the date for the annual meeting; shall present at each annual meeting nominees for members of the nominating committee; shall act on admission of all associate members, regional groups and junior branches and in special cases may elect to voting membership persons of high qualifications but otherwise ineligible; shall consider matters of general policy or welfare of the organization and present its recommendations at the annual meeting of the Society.

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*As revised and adopted at the Philadelphia meeting, January 1, 1941.

Section 3—*Nominating Committee:* There shall be a committee on nominations consisting of two members from each of the sectional groups who shall be nominated by the executive committee and elected by ballot at each annual meeting of the Society. It shall be the duty of this committee, at the following annual meeting to present a list of nominees for the various offices, committees (except the Nominating Committee), representatives, and sectional chairmen who shall be selected after consultation with the sections. This committee shall also nominate referees and alternates upon special subjects of investigation or instruction which may be referred to it for consideration by this Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned to them and to report the present status of the same.

Section 4—*Program Committee:* There shall be a committee on program, consisting of five (5) members, of which the secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society. It shall receive titles and arrange the program of the annual meeting; arrange symposia; accept or reject titles, and may invite non-members to participate.

Section 5—*Editorial Committee:* There shall be an Editorial Committee consisting of five members. One member shall be elected each year to serve for five years. It shall be the duty of this committee to formulate the editorial and publication policies of the Society; to assist the Secretary in reviewing and editing papers and shall have final authority to reject any paper deemed not worthy or unsuitable for publication in the Proceedings.

Section 6—*Membership Committee:* There shall be a committee on membership whose duties shall be the promotion of membership in the Society.

Section 7—*Auditing Committee:* There shall be a committee to audit the books of the Society and report their condition at each annual meeting.

Section 8—*Committee on Local Arrangements:* There shall be a committee on local arrangements who in cooperation with the Secretary-Treasurer will have charge of all local arrangements for the annual meeting.

Section 9—*Quorum:* Ten members of the Society shall constitute a quorum for the transaction of business at a regularly called meeting of which at least 30 days notice shall have been given to members.

Section 10—*Annual Dues:* The annual dues of the Society shall be five dollars.

Section 11—*Amendment to the By-Laws:* The by-laws may be amended at any regular meeting by a two-thirds vote of members present providing a copy of such amendment has been sent to all members at least 30 days prior to the meeting.

Section 12—*Regional Groups:* Upon the presentation of a petition signed by ten or more members of this Society residing within a stated region, the executive committee may approve the formation of a regional group affiliated with this Society. Such group must elect as a minimum number of officers a chairman, a vice-chairman and a secretary and shall present an annual report to the Secretary-Treasurer of the national Society to include the names of its officials and a review of its meetings or other activities. Publication of this report in full or in part shall be made in the Proceedings of this Society. Papers presented at regional group meetings may be published on the same basis as papers presented at the regular annual meeting.

Section 13—*Junior Branches:* A student horticultural group at a college or university, operating under the supervision of a member or members of this Society, may organize as a Junior Branch of the American Society for Horticultural Science upon approval of the executive committee and the payment of an annual fee of five dollars for the branch. Each branch shall receive a copy of all publications of the Society. Such a branch shall elect a chairman, a vice-chairman and a secretary-treasurer and shall present an annual report of its activities to the national Secretary-Treasurer. Such groups may hold meetings in conjunction with the annual meetings of this Society and a report of such meetings, not including individual papers, may be included in the Proceedings.

Tree and Soil Response to Cultural Treatments of Peach Orchards in South Central Pennsylvania[1]

By Nelson J. Shaulis,[2] *New York State Agricultural Experiment Station, Geneva, N. Y.*

The use of cover crops for soil maintenance in peach orchards is a controversial subject because it involves the amount of competition by sods or cover crops to which it is practical to subject peach trees. Some of the studies on this problem have been reported by Bregger and Musser (3), Cullinan and Weinberger (5), Havis, (8), and Olney and Armstrong (10).

The object of this investigation was to study methods of peach orchard soil management to further both peach production and soil conservation in South Central Pennsylvania. The author was responsible for the soils investigations and for special tree and cover crop studies necessary in connection with the soils work. Professor C. O. Dunbar was responsible for that part of the work involving the general tree performance and orchard operations. A report by Dunbar, Anthony and Kinter concerning the more practical pomological aspects of the investigation will be published separately.

Description of Plots

The C. E. Raffensperger and the William Oyler orchards are in Adams County, Pennsylvania. In Franklin County, plots are in the orchard now owned by Walker Brothers, formerly by the late H. W. Skinner.

Many of the peach orchards in these and adjacent counties are on flanks of hills where slopes of 6 to 10 per cent are common. Rainfall intensities are greatest in June, July, and August when it is least desirable to have growing covers in the peach orchard. These two factors, in combination with soils which are not erosion resistant, make runoff and erosion control in peach orchards a difficult problem.

Raffensperger Orchard:—The soil is Penn shale loam. A reddish brown sandy loam to loam extends to 6 to 8 inches; there, reddish silt loam to clay loam is found which grades into soft, red, disintegrated shale and sandstone at 20 to 50 inches. The important characteristics are shallowness of good rooting medium, and imperfect drainage. The peach tree roots penetrate to about 2½ feet in the cover crop plots. In the mulch plots, bedrock is present in the 14 to 24 inch depth. The parent rock is Gettysburg Shale (Triassic) which consists of thick red shale and soft red sandstone. The soil is very erodible. The volume weight of the soil in the surface 6 inches is 1.4 to 1.6; in the second foot it is 1.6 to 1.9.

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[1] Authorized for publication on July 17, 1945 as paper No. 1285 in the Journal series of the Pennsylvania Agricultural Experiment Station.

[2] This is a progress report of part of the cooperative work of the Pennsylvania Agricultural Experiment Station and the Research Division of the Soil Conservation Service. Portions of the 1939 and 1940 data are from a thesis submitted by the author to the Faculty of the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, June 1941.

The author is grateful to Dr. R. D. Anthony and Professor C. O. Dunbar of the Department of Horticulture, The Pennsylvania State College for their counsel and cooperation in the field, and in preparing this report.

The Soil Conservation Research Station, State College, Pa. supervised by Dr. Nolan Farris until 1940 and by Mr. Earl B. Kinter to date, has been continually helpful.

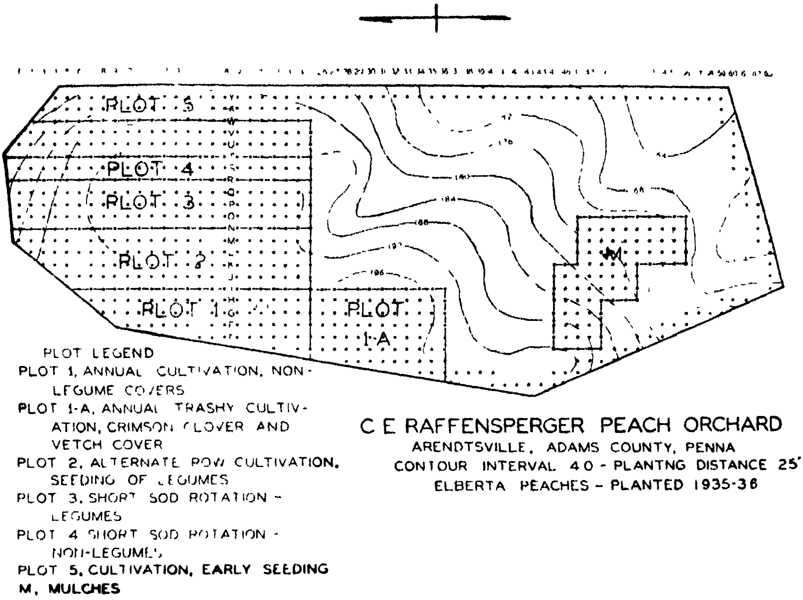
PLOT 5
PLOT 4
PLOT 3
PLOT 2
PLOT 1
PLOT 1-A
M
PLOT LEGEND
PLOT 1, ANNUAL CULTIVATION, NON-LEGUME COVERS
PLOT 1-A, ANNUAL TRASHY CULTIVATION, CRIMSON CLOVER AND VETCH COVER
PLOT 2, ALTERNATE ROW CULTIVATION, SEEDING OF LEGUMES
PLOT 3, SHORT SOD ROTATION - LEGUMES
PLOT 4 SHORT SOD ROTATION - NON-LEGUMES
PLOT 5, CULTIVATION, EARLY SEEDING
M, MULCHES
C E RAFFENSPERGER PEACH ORCHARD
ARENDTSVILLE, ADAMS COUNTY, PENNA
CONTOUR INTERVAL 4 0 - PLANTNG DISTANCE 25'
ELBERTA PEACHES - PLANTED 1935-36

FIG. 1. Map of experimental plots in Raffensperger Orchard.

In Plots 1, 1A, 2, 3, and 4, Elberta peach trees were planted 25 x 25 feet in 1935. The orchard was intercropped to corn in 1935–36. The cover crops were seeded in 1937. Fig. 1 presents the map of the Raffensperger Orchard.

Table I affords a description of the cultivation and the amount of nitrogen fertilizer applied to each plot. The two major modifications in treatment were the increase in cultivations in plots 2 (cultivated), 3, and 4 after 1939 and, in these same plots, the change towards less cover by postponing seeding from May to August after 1941. Each of these changes was made after a drought year and was a recognition of the depressing effect upon moisture supply which growing soil covers can exert during the hot summer months.

Walker Brothers Orchard:—This is a vigorous block of mature Elberta peach trees planted 23 x 23 feet. The soil is of limestone origin, is deep, fertile and well drained. The surface soil is a sandy loam because of the deposition of sandstone fragments on the limestone-derived soil. Each treatment had two plots; each was a row of 20 trees. Alternate rows were border rows.

The major comparison was between plots with a cover crop of

TABLE I—OUTLINE OF TILLAGE AND NITROGEN FERTILIZATION. RAFFENSPERGER CULTURAL PLOTS 1939–1943

Plot	Treatment	1939‡‡	1940	1941	1942	1943
1**	Tillage‡	May 6 June 1, 28, July 5 and seeded§ July 17	May 7, June 17, and seeded§ July 17	April 28, May 12, 23 June 28, and seeded§ July 15	April 29, seeded§ July 9	May 7, June 12, seeded§ July 15
	N fertilizer* pounds per tree	April 20. 3 pounds broadcast	May 4. 4 pounds broadcast	April 19. 3½ pounds ringed	April 16. 3 pounds ringed	April 23. 4 pounds ringed
1A**	Tillage	As Plot 1	June 17, seeded§ July 17	June 21, seeded§ July 15	Seeded§ July 8	June 12, seeded§ July 15
	N fertilizer pounds per tree ringed	As Plot 1	As Plot 1	April 19 3½ pounds June 9. 3½ pounds	April 16. 4 pounds May 29. 2½ pounds	April 23. 4 pounds May 24. 2½ pounds
2† Cultivated	Tillage‡	Seeded§ May 6	May 7, seeded§ May 18	April 28, May 26 seeded§ June 21	April 24, July 9 seeded§ August 4	May 7, June 12, July 15, seeded§ August 3
2† Sod	Number of mowings	3	3	5	2	2
	N fertilizer pounds per tree ringed	April 30, 3 pounds broadcast May 23, 1½ pounds	May 4, 2 pounds broadcast. July 9, 2½ pounds	April 19, 3½ pounds June 10. 3½ pounds	April 16, 4 pounds July 16, 2½ pounds	April 23, 4 pounds June 22, 2½ pounds
3†	Tillage‡	None	As Plot 2 Cultivated	April 28, May 26, seeded§ June 21	April 29, July 9 seeded§ August 4	June 12, July 15, seeded§ August 3
	Number of mowings	3	3	2	1	0
	N fertilizer Pounds per tree ringed	As Plot 2	As Plot 2	As Plot 2	As Plot 2	As Plot 2
4††	Tillage‡	May 6	As Plot 2 Cultivated	May 26	April 29, July 9	May 7, June 12
	Number of mowings	2	2	3	3	0
	N fertilizer Pounds per tree ringed	As Plot 2	As Plot 2	As Plot 2	As Plot 2	As Plot 2

*All N fertilizer as pounds nitrate of soda.

**Plot 1 seedings are of Sudan grass and millet; plot 1A of crimson clover, vetch and millet.

†Plot 2 and 3 of sweet clover, alfalfa, alsike and red clover through 1940, in 1941–1943 seedings were of Ladino, red and alsike clovers.

††Plot 4 is of orchard grass.

‡Excepting Plot 1, all tillage prior to seeding was trashy, or incomplete; some residue remained on the surface.

‡‡In major items, treatment in 1938 was similar to that in 1939.

§Seeding implies thorough seedbed preparation.

crimson clover, vetch, rye, and millet and those with a sod mixture of Ladino clover, perennial rye grass, and red fescue. The former were seeded in July 1941, disked and reseeded in July 1942, disked in May 1943 and then seeded in mid-July 1943. Very successful stands were obtained in 1941 and 1942; in the fall of 1943, following a very dry summer, two-thirds of the soil was covered but only 10 per cent by living cover.

The sod mixture was seeded in May 1942. It was mowed in the fall of 1942 and trashily cultivated four times until early July, 1943. It was estimated on September 30, 1943 that 80 per cent of the soil was covered; 65 per cent by living cover. The trees in the sod mixture received a July application of 2 pounds of nitrate of soda. All the trees received 4 pounds earlier in the spring.

In 1942, the remainder of the orchard had no seeded cover crop following the May disking of crimson clover and vetch. Until October 1943 the cover was a light stand of weeds. Two of these rows were studied and labeled "weed and fallow".

William Oyler Orchard·—This 1940 planting of peaches is on the contour. The soil is Ashe loam and, although deep, is not fertile. The rye grass and sod mixture plots in 1942 and 1943 were cultivated in early spring, but not in late summer. Cultivation of the crimson clover, vetch and rye plot was delayed, and the seedbed was prepared in mid-July. The ladino plots likewise had more growing cover in the spring than in the summer. The major concern in the study of cover crops is the time of cover competition and the degree of this competition, especially for water and nitrogen.

PART I. RESPONSE OF TREES TO COVER CROP PRACTICES

YIELD AND SIZE OF FRUIT

For the Raffensperger orchard, data on peach yield and size are presented in Fig. 2a, 2b, and 2c. In each of the years 1939–1943, it was necessary to thin the fruit on all the plots. Even though the trees were thinned as nearly uniformly as possible, the effects of variations in setting could not be avoided. Variation in yield among plots was, however, more influenced by the tree size and fruit size than by the number of fruits set per unit of twig growth. The reduced pruning weights, number of nodes, tree height and tree spread of Plots 2, 3, and 4 all indicate the reduced bearing area of the trees which had been subjected to the increase competition by these modified sods.

In 1939, differences in peach size among plots were due to low rainfall and the reductions in soil moisture in the plots with heavy cover crops. The growth curves of certain selected fruits (Fig. 3), and the soil moisture data (Fig. 10), indicate moisture deficits in the peaches and in the soil during 1939. Plots 1, 1A and the mulched plots containing more plentiful soil moisture produced peaches of marketable size in that year. In Plots 2, 3, and especially 4, the fruit was small, green, and ill-tasting.

In 1940 the growing season had a nearly normal rainfall excepting the 5.1 inches of rain (Fig. 4), in the 7 days prior to harvest. With high rainfall the continuous cover plots, (2, 3, and 4) were in a much

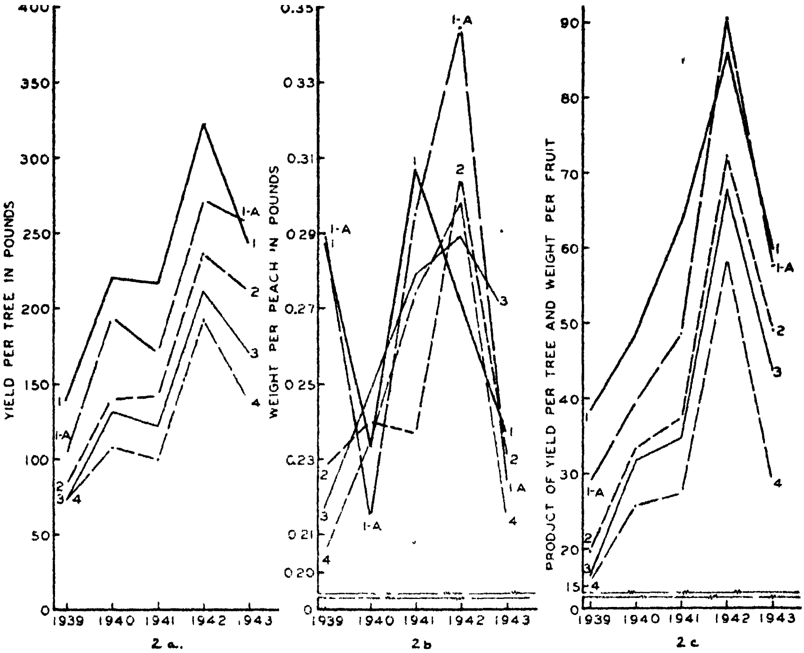

FIG. 2. Peach yield and size data. Raffensperger Orchard. 2a (Left) Peach yield; 2b (center) peach size; 2c (right) yield adjusted by size differences.

better position than in 1939 with relation to the cultivated plots. Peaches from Plot 1 were inferior in size, color, firmness and flavor; the fruit was much higher in water content as shown in Table II. All these sampled fruits were in the size class 2 to 2¼ inches. For the fruits with green ground-color, the difference is highly significant; for the fruits with yellow ground-color, it is significant (P = .04).

TABLE II—MOISTURE CONTENT OF MATURE ELBERTA PEACHES IN CULTIVATED PLOTS AND IN A COVER OF ORCHARD GRASS. RAFFENSPERGER ORCHARD SEPTEMBER 5, 1940

Plot	Number of Trees Sampled	Number of Peaches Sampled	Percentage Water, Dry Basis	
			Green Ground-Color	Yellow Ground-Color
1 Cultivation and Sudan grass	5	100	941	884
4 Orchard grass	5	100	854	840

In 1941, as in 1939, rainfall during the growing season was low (Fig. 5a). Fruits from Plots 1 and 1A were definitely larger than those from plots with more continuous cover. The relative increase in weighted yield[3] (Fig. 2c), over that in 1940 is a good indication of

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[3] This yield and size product is really the quotient of the square of the yield to the number of fruits in that yield.

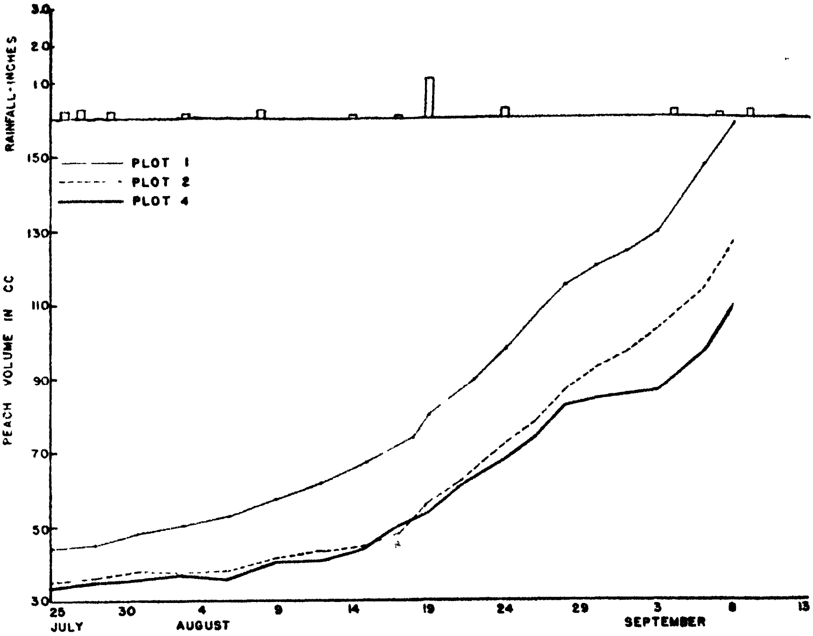


FIG. 3. Volume of selected Elberta peaches in Raffensperger cultural plots, 1939.

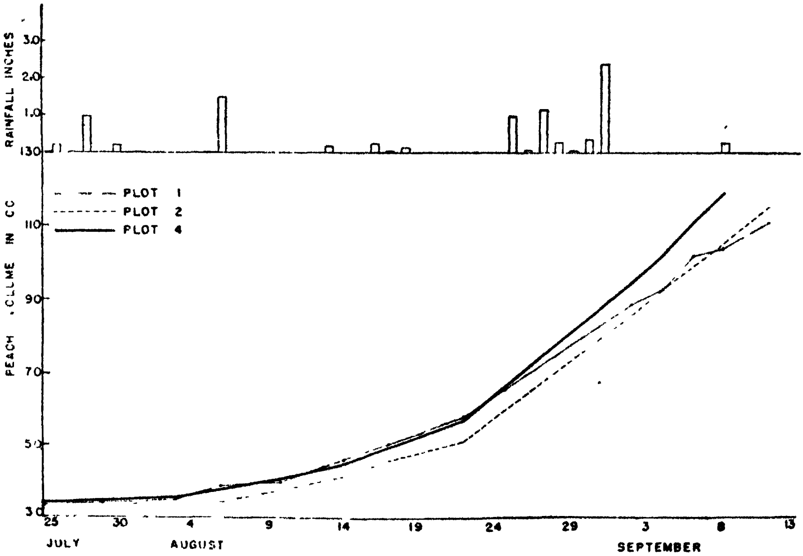


FIG. 4. Volume of selected Elberta peaches in Raffensperger cultural plots, 1940.

the moisture deficits occasioned by the treatments. The increased size of the peaches in Plots 3 and 4 in 1941 over that in 1939 is due, at least in part, to the increase in trashy cultivations and, thereby, more available moisture.

The high rainfall during the growing season (Fig. 5b) of 1942 greatly increased the size and yield in all plots. A calculation of the yield per unit cross-sectional area of the trunk shows that Plots 1 and 1A are not superior in this respect to Plots 2, 3, and 4. Yields are greater in Plots 1 and 1A because the trees are larger even though they are the same age.

In 1943, (Fig. 5c), the rainfall and available soil moisture were less than in 1939 or 1941, the other dry seasons. Irrigation to save the crop was started on August 25. Each of the trees received at least 300 gallons of water. Plot 4 had the most continuous cover, the smallest peaches, and the least yield. Plots 1 and 1A, because of large tree size, had large yields even though their fruits were smaller than in the two previous years. One half of Plot 2 was fallow and in the last month of the growing season Plot 3 had little growing cover. Hence, they were intermediate in fruit volume increase with respect to Plot 4 and Plots 1 and 1A.

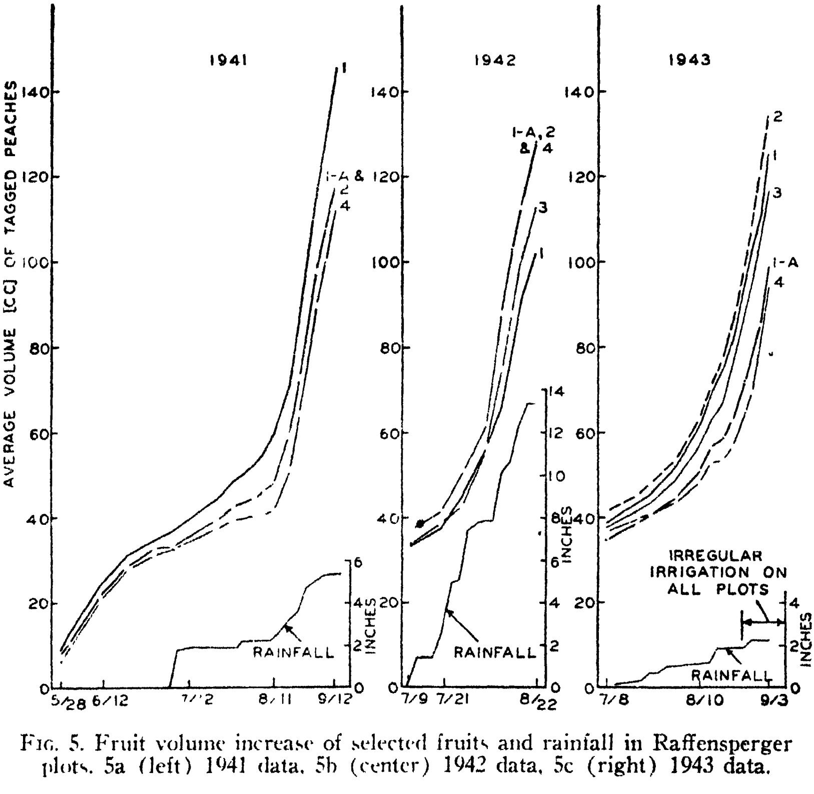


FIG. 5. Fruit volume increase of selected fruits and rainfall in Raffensperger plots. 5a (left) 1941 data, 5b (center) 1942 data, 5c (right) 1943 data.

Fruit Volume Increase

Raffensperger Orchard:—The rate of fruit enlargement has been used by many investigators as an index of orchard soil moisture. It has been useful in this study; 3 years of both this and intensive soil moisture sampling have led to the conclusion that fruit volume data are reliable indications of relative soil moisture deficits for the peach. Six peaches were tagged on each of six trees in each treatment. In 1939 and 1940, the circumference and volume, by water displacement, of several hundred Elberta peaches of all sizes were measured. The table, prepared from these data, for the conversion of fruit circumference to volume has been used in this study.

Fig. 3 presents the data for three of the 11 plots studied in 1939. Plot 1 was cultivated and had relatively high moisture; Plot 2 had alternate rows cultivated; Plot 4 was maintained as a sod in 1939 and its soil moisture at times was below the wilting point. The rate of increase of fruit volume is in exactly the same order in the different plots as that of soil moisture.

Fig. 4 presents data for 1940, when soil moisture was high during the growth period. The influence of this very high rainfall during harvest is shown in Table III.

TABLE III—Excessive Rainfall Effects on Fruit Size in Various Cultural Treatments. Raffensperger Orchard, 1940

Plot	Rainfall Aug 28 to Sep 8	Fruit Volume (cc)		Fruit Volume Gain Per Peach Aug 29 to Sep 8
		Aug 29	Sep 8	
1	5.1	75	104.0	29.0 cc per peach
2	5.1	68	105.5	37.5 cc per peach
3	5.1	72	109.5	37.5 cc per peach
4	5.1	74	119.0	45.0 cc per peach

In 1941, the fruits of Plots 2, 3 and 4 with relatively continuous covers had a reduced rate (Fig. 5a) of volume increase at the beginning of the final swell. Mid-August rains removed the moisture deficiency, and peach size on all plots was commercially acceptable though Plots 1A, 2, 3 and 4 had smaller fruit than Plot 1.

In 1942, the best growing season of the period 1939–1943, there were no measured moisture deficits (Fig. 5b). The fruit volume curve for peaches on Plot 1 is lowest, as in the other year of high rainfall, 1940. In this year it is apparent that the growing cover did not reduce fruit size.

The 1943 data (Fig. 5c) can be studied only to August 23 because irrigation affected fruit size thereafter, as shown by measurements on August 26. For Plot 4, the curve is like that in 1941. The low position of Plot 1A, just as that of Plot 3 in 1942, does not represent such a low rate of fruit volume increase as the final measurement shows. The important part of each curve is its slope; the relative positions of any two curves is influenced by the size of the peaches tagged for measurements.

Low nitrogen treatments, such as a grass sod or a sawdust mulch, will cause the fruit to mature at an early date, *i. e.* to show a very marked increase in fruit volume when the fruit growing with heavy nitrogen fertilization or in manure mulch has not yet started the final swell. Such differences in rate of fruit volume increase do not bring about sharp irregularities in the curves. Changes in rate of fruit volume increase caused by a reduction of the moisture deficit, however, cause an abrupt change in the slope of the curve of fruit volume.

Walker Brothers Orchard:—Fig. 6a presents the fruit volume curve for tagged fruit in the plots at Walker Brothers in 1943. There is no significant difference between these mean curves. This was true also for 1942. A more extensive sampling of the fruits at three harvest dates showed no size differences between treatments for the first and second pickings, but a somewhat larger fruit size in the crimson clover plot than in the sod mixture at the last picking. The explanation for the similarity, as contrasted to Plot 4 and Plot 1A at Raffensperger's, is that the deeper, more fertile soil afforded a much larger water storage than that of Raffensperger's orchard.

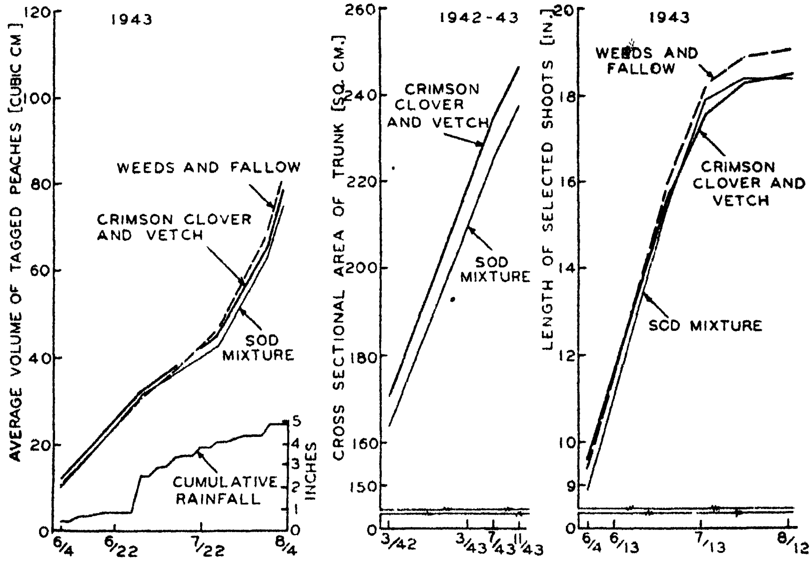


FIG. 6. Peach size and tree growth in Walker Bros. orchard. 6a (left) rate of volume increase of tagged peaches; 6b (center) trunk size increase; 6c (right) shoot elongation.

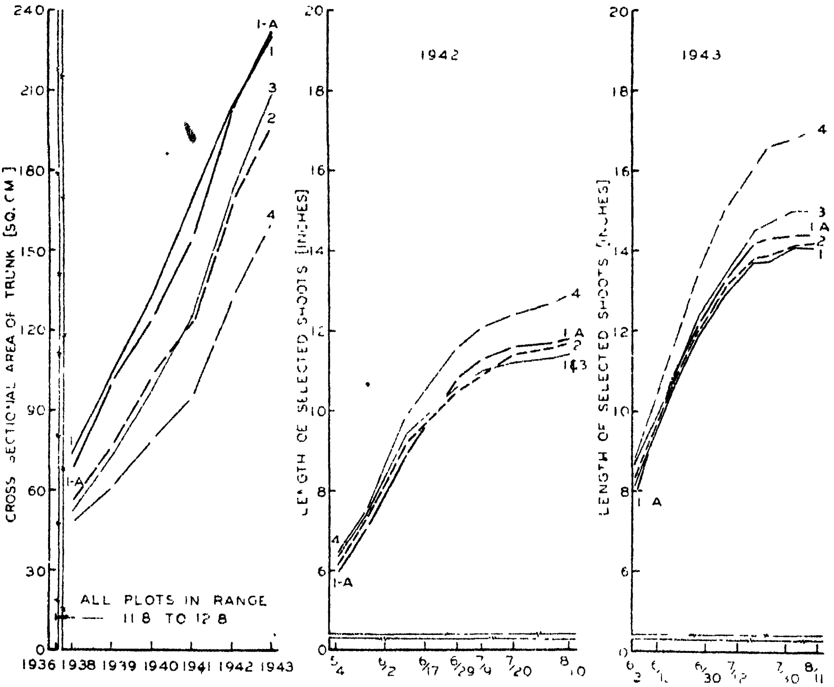
INCREASE IN AREA OF CROSS SECTION OF TRUNKS

Raffensperger Orchard:—Each winter the circumference of each tree included in this study was measured at a painted ring on the trunk. The area was calculated on the assumption that the trunks are circular in cross section. There is a closer association of yield to trunk cross-section area than to trunk circumference.

The mean trunk cross section areas, hereafter called trunk areas, are presented in Fig. 7a. The regular gain in trunk area of Plot I shows that it is least affected by droughts and cover competition. The covers of Plots 2, 3 and 4 effected a series of "droughts" up to 1942. The greatest gains in trunk size as well as in yield were made in 1942, a year of high rainfall.

The average yield per unit of trunk area, computed by dividing the mean yield of trees in a plot by the mean trunk area was found to be similar on the different plots. This stresses the importance of getting the tree to mature size as quickly as possible. In this orchard the heavy growing-season vegetative covers were established when the trees were in the third season. On soils as shallow as this, such a practice was not a good one.

Walker Brothers Orchard:—The data are presented in Fig. 6b. There is no statistically significant difference between the mean trunk areas graphed there.



7a. 7b 7c

FIG. 7. Peach tree growth data from plots in Raffensperger orchard. 7a (left) trunk area increase; 7b (center) elongation of tagged shoots in 1942; 7c (right) elongation of selected shoots in 1943.

ELONGATION OF SELECTED SHOOTS

Raffensperger Orchard:—Figs. 7b and 7c present the data for some of the plots in the Raffensperger Orchard for 1942 and 1943. These data are mean lengths per treatment of 36 shoots tagged for the fruit volume increase study. They are all in the lower half of the tree and are shorter than many of the shoots in the top of the tree. All measurements are made to the tip of the leaf which makes the longest shoot-leaf combination. This device surmounts the difficulty of locating the "tip" of the shoot when it is rapidly elongating.

The one point which these graphs illustrate best is that the average length of shoots selected in this manner cannot be used to predict tree growth or yield. Trees in Plot 4 are smallest, yet in 1942, a season of high rainfall, or in 1943 when two trashy cultivations were given while shoot growth was most rapid, the average elongation of these selected shoots was greater than in any other plot. Low pruning weights and trunk area emphasize that the number of shoots is as important as length per shoot. The average weight of 1-year-old wood pruned from trees in 1941 in Plots 1, 1A and 4 was 11.5, 10.5, and 4.8 pounds per tree respectively. In 1939 and 1940 the relative pruning weights for Plots 1, 2, 3, and 4 were 100, 37, 43 and 28 respectively.

Walker Brothers Orchard:—Fig. 6c presents the shoot elongation data for 1943. These, as in 1942, show no marked differences among the plots.

LEAF AREA IN 1940

Leaf area per node was determined on the leaves from the central one-third of each of 10 shoots on each of five trees per treatment. These measurements are presented in Table IV. The greater leaf area per node in Plot 4 than Plot 1 presented the same difficulty in interpretation as did shoot elongation.

A count of all the nodes on 1-year wood was made in the winter of 1940. These data are in Table IV.

TABLE IV. LEAF AREA AND NODAL COUNT OF TREES IN RAFFENSPERGER CULTURAL PLOTS 1940

Tree	Number of Nodes		Total	Leaf Area (Square Inches)	
	On Tree	On Prunings		Per Node	Per Tree
			Plot 1		
H19	12,627	7,813	20,440	5.80	———
E19	11,275	12,654	23,429	6.15	———
K17	8,540	12,952	21,492	5.76	———
			21,954	5.89*	131,400
			Plot 2		
K12	6,631	7,007	13,636	7.10	———
K15	8,824	4,674	13,498	6.64	———
K10	9,617	7,067	16,684	6.66	———
			14,407	6.59*	96,406
			Plot 3		
S10	6,899	4,339	11,238	6.43	———
S15	7,237	3,761	10.998	6.59	———
S20	6,786	6,111	12,987	——	———
			11,711	2.01*	82,094

*Mean of five trees.

The relatively high leaf area per node in the Plots 2 and 4 is evidence of the good growing conditions in the 1940 season. The low number of nodes per tree is evidence of the less favorable growth conditions in some previous year or years (as in 1937 and 1938 drought years). The effect of this restricted growth in 1939 on the 1940 growth could be likened to a severe pruning. The data of Table IV indicate that many more growing points were removed from Plot 1 than from Plots 2 and 4.

The several tree measurements expressed on a basis relative to Plot 1 are shown in Table V.

TABLE V—PEACH TREE INDICATORS OF PLANT RESPONSE TO ORCHARD CULTURAL TREATMENTS. RAFFENSPERGER ORCHARD 1939–1941

Plot	1939 Record	1940 Records					1941 Records		
		Yield		Number of Nodes Per Tree	Leaf Area Per Tree	Trunk Area Per Tree	Yield	Weight of Twig Prunings	Trunk Area Per Tree
	Yield Plot Mean	Plot Mean	Three Trees Used in Nodal Count						
1	100	100	100	100	100	100	100	100	100
2	67	70	69	68	73	72	67	55	68
4	53	54	58	53	62	51	47	46	55

These five criteria, number of nodes per tree, leaf area per tree, trunk area, weight of twig prunings, and yield, each establish the same order of response to the cultural treatments. Average shoot length, leaf weight per node, or fruit size do not take into account the numbers of shoots, of nodes or of fruits and, hence, can be misleading.

DISTRIBUTION OF MULTI-LEAVED NODES

In 1943, counts were made of the number of leaves in excess of one per node on each node of 10 shoots per tree and 10 trees per treatment of certain contrasting treatments in the Raffensperger orchard. Counts were kept separate for the basal, central and tip portions of each shoot. Dorsey (6) has established five vigor classes for nodes. Here only two classes were recognized, single-leaved nodes and multi-leaved nodes, but emphasis was placed on their position on the shoot. Table VI illustrates the use of this count.

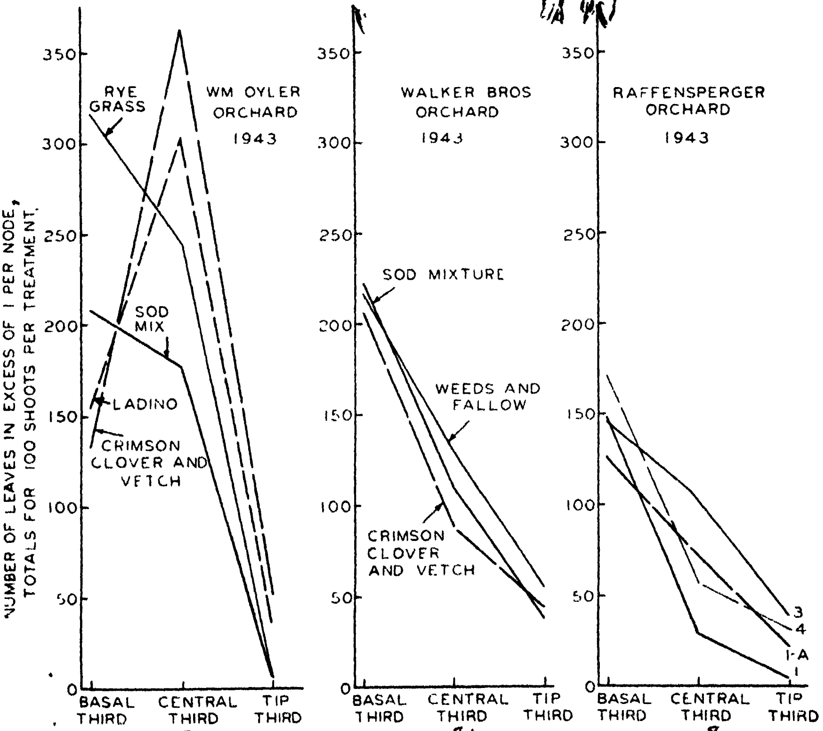
TABLE VI—COUNT OF MULTIPLE-LEAVED NODES ON SELECTED SHOOTS OF ELBERTA PEACH TREES. RAFFENSPERGER ORCHARD, 1943

Treatment	Number of Leaves in Excess of One Per Node Mean Per Tree of 10 Sampled Shoots			
	Basal Third of Shoot	Central Third of Shoot	Tip Third of Shoot	Total for Entire Shoot
	Legume and weed			
Sod since 1938				
5 pounds $NaNO_3$ per tree per year*	4.2	1.5	0.0	5.7
15 pounds $NaNO_3$ per tree per year*	9.5	3.3	0.0	12.8
	Alternate Rows and Fallow			
5 pounds $NaNO_3$ per tree per year*	10.1	1.3	0.2	11.6
15 pounds $NaNO_3$ per tree per year*	11.2	7.1	1.1	19.4
Rye until June; then fallow.	0.9	7.4	0.8	9.1
Ryegrass. Early cultivation only	6.3	2.8	0.7	9.8

*In 3 applications.

In the comparisons of 5 pounds and 15 pounds of sodium nitrate the distinction lies in the total number of leaves in excess of one per node. The higher nitrogen application and the alternate row cultivation have increased the leaf production per node. In contrast, the trees in the rye and ryegrass had the same total of extra leaves per shoot, but the leaves in excess of one per node varied in their distribution on the shoot. On the basal third of the shoot, four early trashy cultivations have made the trees in the ryegrass cover superior to those in the rye cover. In the central third, the effect of the rye fallow is noted in contrast to that of the reestablished ryegrass sod.

Fig. 8c presents similar counts for Plots 1, 1A, 3 and 4. In Plots 1 and 4, cultivation was frequent in spring, after which Sudan grass and orchard grass respectively, were established. There were numerous "extra" leaves on the basal third of the shoots; but a reduced number of multi-leaved nodes on the central and tip portions. Plots 3 and 1A had delayed spring cultivation, then very slight green cover in the latter part of the growing season. This is associated with fewer extra leaves on the basal third of the shoot and a relatively high number on the central and tip portions.



8a. 8b. 8c.

FIG. 8. Number and position of multi-leaved nodes on selected shoots of peach trees. September 1943. 8a (left) Oyler Orchard; 8b (center) Walker Brothers Orchard; 8c (right) Raffensperger Orchard.

Figs. 8b and 8a present similar data for the Walker Brothers orchard and William Oyler orchard. The relative numbers of multileaved nodes are subject to interpretations similar to those for the Raffensperger orchard, and these will be omitted.

MULCH EXPERIMENT

At the right side of Fig. 1 is shown the area used for the triplicate three-tree plots for each of the five treatments: straw, straw + N, horse manure, sawdust, and hoed. The Elberta peach trees in these plots were planted in the spring of 1936, and grown as a portion of Plot 1 until April 1939 when the mulches were applied. The slope was 8 to 12 per cent and the soil was shallow and severely eroded.

The object was to study mulch quality. The least quantity of mulch material was applied which would suppress weed and cover crop growth. Thus 1440 pounds of mixed sawdust (360 pounds of air-dry matter), 100 pounds of straw and 530 pounds of fresh horse manure (150 pounds of air-dry matter) were applied per tree. They were placed 2 feet beyond the branch spread and to within 1½ feet of the tree trunk. They were renewed in 1940 and 1943.

In 1939 the hoed plots had some crabgrass; in 1940–1943 they were kept bare by more frequent hoeing.

Two pounds of nitrate of soda were applied to each of the straw + N trees in 1939, 1941, and 1943. None of the other mulches or hoed trees received any fertilizer in 1939–1942.

The sawdust brought about the most nitrogen starvation as well as the least tree growth and yield.[4] The growth and yield of the unfertilized hoed trees was unsatisfactory. Straw + N was superior to straw alone on the basis of trunk area, weight of prunings, and yield.

Since the manure was least effective in suppressing weed growth, it had less soil moisture in drought periods, and peach size was reduced thereby below that of straw or sawdust mulch.

Four pounds of nitrate of soda per tree in 1943 corrected the nitrogen starvation in the trees with the sawdust mulch. It is thought that the harmful effect was due to a reduction in the availability of soil nitrogen. Even if sawdust were free of charge, so much of it is required for good mulch effect that the costs of hauling would not be justified. Furthermore, it is easily floated away by rain or blown away when dry.

Table VII presents the indexes of color of the fruit from the mulch plots. A high index represents high red coloration; 36 is the highest number on the scale; 9 represents very immature fruit. The data are based on estimates of color at harvest time.

The higher-nitrogen mulches of manure and straw + N delayed fruit coloration in 1939 and 1940. In 1941, the harvest was late; all fruit was well colored and maturity was indicated by the number of dropped peaches.

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[4] A detailed description is to be found in the dissertation by the author, filed in the Library of Cornell University.

TABLE VII—THE INFLUENCE OF MULCH MATERIAL ON PEACH COLOR AND HARVEST DROP. RAFFENSPERGER ORCHARD 1939–1941

Mulch	Color Index			Harvest Drop Peaches Per Tree, 1941
	1939	1940	1941	
Straw + N	20	27	35	13
Manure	20	26	33	16
Hoed	23	31	34	13
Straw	24	31	25	26
Sawdust	27	34	36	35

There was only a slight accumulation of nitrates under any of the mulches at any time. Soil moisture was higher than in Plots 2, 3, or 4 in 1939–1942.

In 1942, slaking tests of soil under the applied mulches showed high water stability. The hoed soil behaved similarly to that in Plot 1.

PART II. SOIL RESPONSE TO PEACH ORCHARD CULTURAL PRACTICES

Baker (2) presents a short review of the literature on soil moisture and nitrates in apple orchards. In his work, nitrate nitrogen was least in the sods, most in the cultivated plots, and was not correlated with apple tree growth. Soil moisture under cultivation was not higher than that in bluegrass or alfalfa. In 1906, Green and Ballou (7) nicely divided the hill country from level country in a discussion of apple orchard cultural practices. Olney and Armstrong (10) did the same for peach orchards.

Li *et al.* (9), Browning and Sudds (4) and Shaulis and Merkle (11) emphasize the desirable physical characteristics and high organic matter content of soils in complete sod or mulch or their modification.

SOIL MOISTURE

The Penn shale loam of the Raffensperger orchard has a moisture equivalent of 22 for the first foot and 22 for the second foot. The permanent wilting percentage determined by the sunflower technique is 7.3 ± 0.25 for the first foot; in the second foot it is 9.3 ± 0.6.

First and second foot samples were taken with a soil tube in two tree squares of each treatment. In each square a 50 to 70 gram sample was taken at two depths at the periphery of each of the four trees of the square. These constitute "tree" samples for any one line. In addition, two samples were taken in the center of the square for a "middle" sample. Each sample was oven dried and the moisture is expressed as the percentage by weight of oven dry soil. Locations of the sampling squares for both lines A and D were within the 200-foot contour lines. Line E is along rows 40 to 45 and has a slope of 6 to 8 per cent.

Fig. 9 shows the soil moisture content under fallow and under a sweet clover cover crop as Plot 2 sod at various depths of sampling and distances from the tree.

Fig. 10 presents the soil moisture data for Line D in 1939. Here the cultivation of Plots 1 and 2-cultivated is associated with a higher

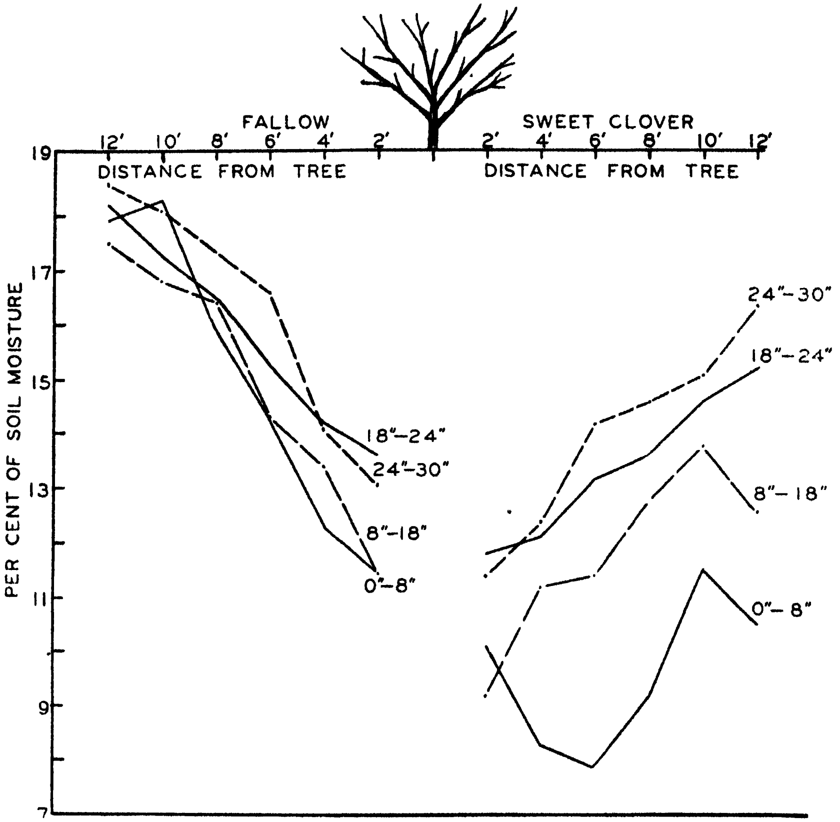

FIG. 9. Soil moisture distribution at four depths, under fallow and heavy cover crop and at various distances from a 3-year old peach tree. Raffensperger Orchard, Row I, 1938.

moisture content than that of the sod Plots 4 and 2-sod. The low soil moisture of sod Plots 2 and 4 drastically reduced fruit size. The soil moisture beneath the mulches was uniformly higher than in the sods. The difference is due to the suppression of growing cover, as evidenced by the lower soil moisture beneath the manure mulch which was least effective in suppressing weeds.

Fig. 11 shows that soil moisture was uniformly higher in 1940 than in 1939. In this graph, Plot 3 is similar to the Plot 2 sod of the 1939 graph. The heavy rains of late August raised the moisture content of the first foot of soil to field capacity in Plots 1, 2, and 3. Plot 4, where the rate of peach volume increase was not retarded, had the least soil moisture in the first foot. These relations did not hold in the second foot.

Fig. 12 presents the content of soil moisture along Line E, an eroded slope south of Plots 1A, 2, 3, and 4, and into which the treatments of these plots extend. There were two heavy high-intensity rains in July

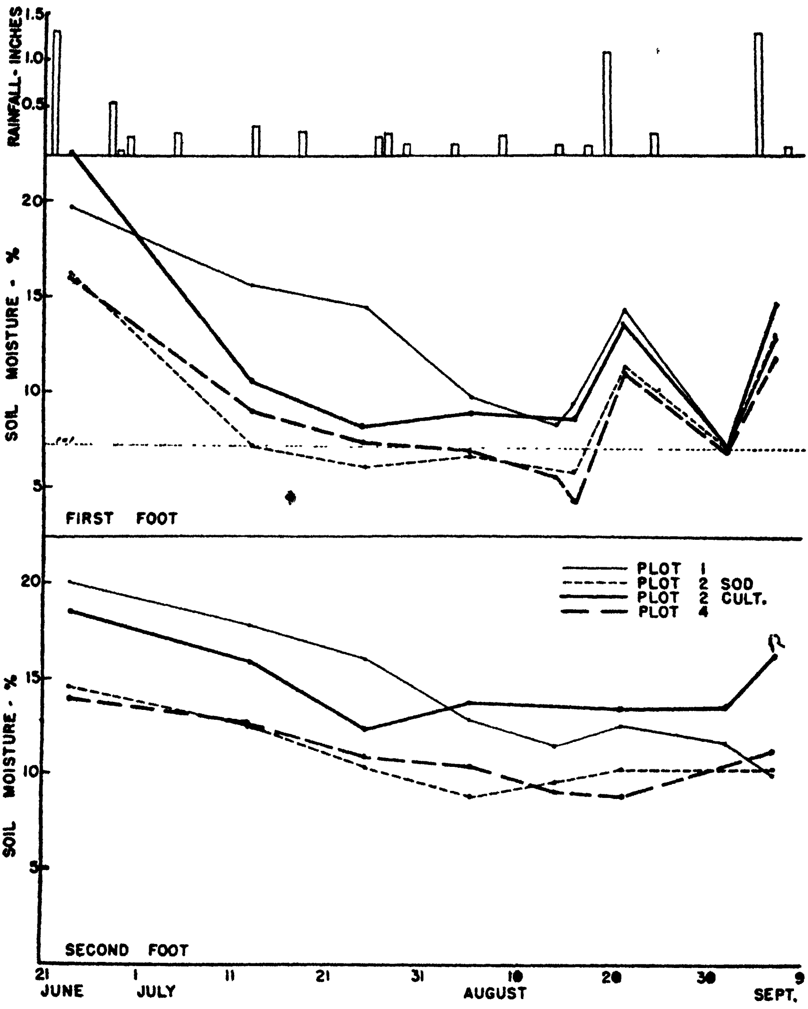

FIG. 10. Soil moisture in Raffensperger peach cultural plots. Line—D middles—1939.

and August, 1940; the soil sampling done before and after these rains shows the effectiveness of the soil management similar to that of Plots 2, 3 and 4 in rainfall absorption. This is in contrast to the lesser rainfall absorption in an area similar to Plot 1A, in which crimson clover and vetch were trashily disked in mid-June and thoroughly disked and reseeded in mid-July. That areas managed similarly to Plot 1A at times have a relatively high moisture content despite low rainfall absorption during the period of reestablishment of the cover crops indicates low moisture withdrawal by growing covers and, hence, the absence of protective vegetation on the soil surface.

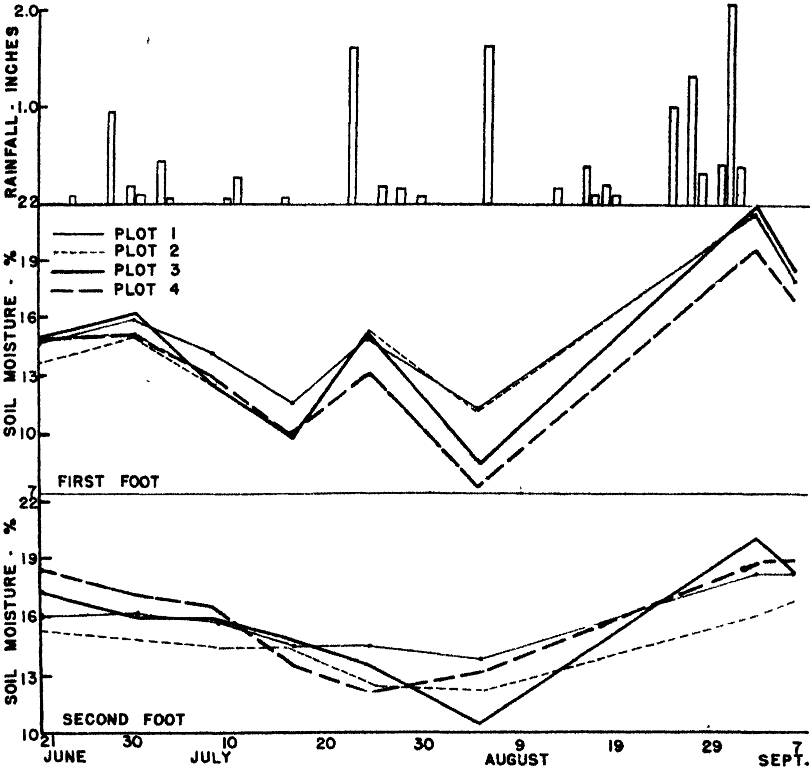

FIG. 11. Soil moisture in Raffensperger peach cultural plots. Line—D trees—1940.

The 1941 data on Line E are similar in many respects to those of 1939 and are not presented.

The relation among ground cover, cover crop incorporation, and runoff control in the Raffensperger and Oyler orchards was presented in a 1940–41 study by Alderfer and Shaulis (1). Their data emphasize the relatively abrupt decrease in infiltration capacity effected by incorporation of a heavy cover crop, relatively slow redevelopment (several months) of the soil-plant relationship which brings about a high infiltration capacity, and the importance of actual ground coverage by either growing or dead plant material in controlling runoff.

SOIL NITRATES

The concentration of nitrates in the water extract of a soil represents nitrate accumulation rather than supply. As far as a moderate to high level of nitrate accumulation represents no nitrogen deficiency and no accumulation represents a nitrogen deficiency, the use of this analysis will serve our purpose. It is not wholly satisfactory.

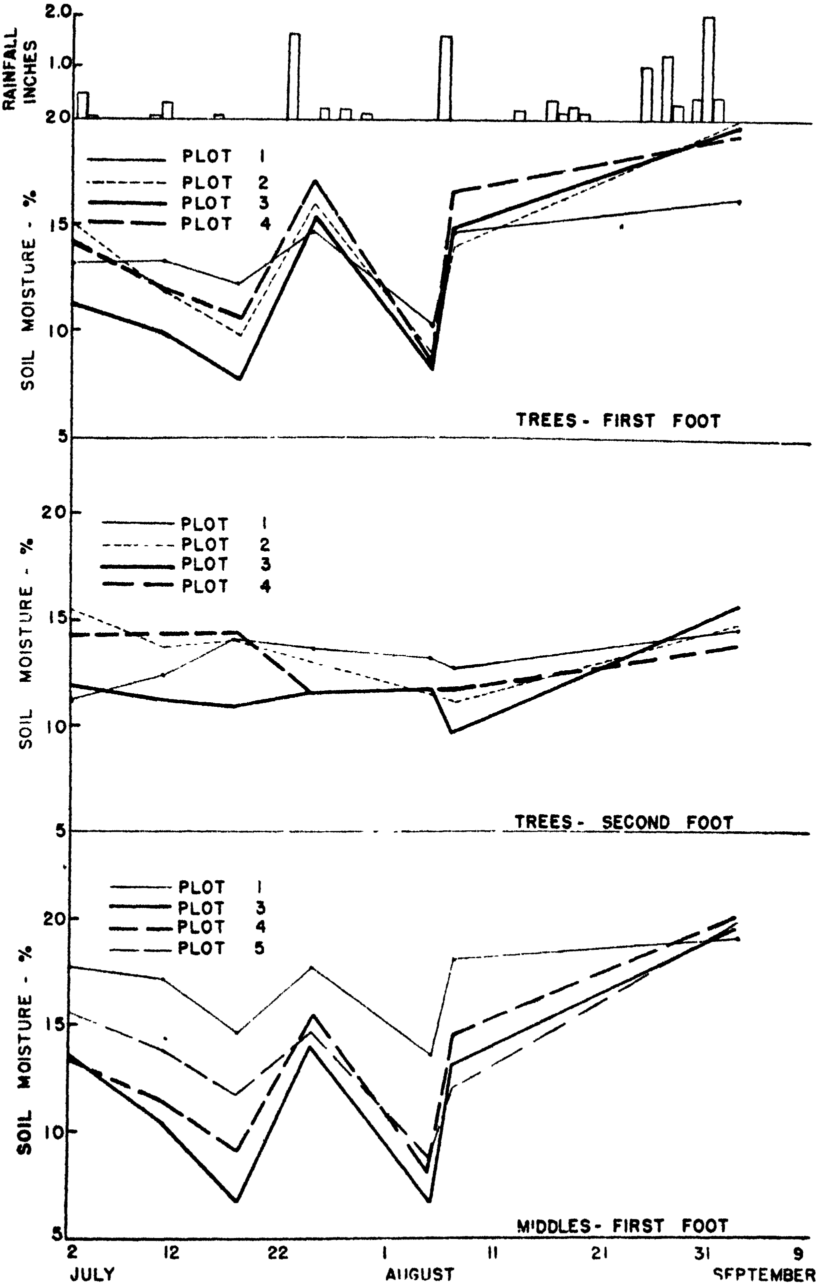

FIG. 12. Soil moisture in Raffensperger peach cultural plots — Line—F—1940.

The diphenylamine spot plate method was used on four composites each of four to six cores for each treatment. Samples were taken at 6-inch intervals to 18 inches.

Table VIII shows the concentration of nitrates at varying distances from the trees and the effect of ring applications. This may be important in influencing root extension toward the center of the tree square. The least cultivated plots, 2 sod and 4, have the least soil nitrates in the center of the square.

TABLE VIII—SOIL NITRATE DISTRIBUTION BETWEEN PEACH TREES. MEANS OF FOUR TO EIGHT ANALYSES OF SIX-CORE COMPOSITES TAKEN AT 0–12 INCHES. RAFFENSPERGER ORCHARD, JULY 17, 1941

Plot	Nitrate Concentration as PPM in One to Five Soil-Water Extract							
	Distance From Tree (Feet)							
	2	4	6	8	10	12	14	16
1	0	4	8	4	9	Trace	4	12
2 (cultivated)	3	15	18	16	7	4	5	15
3	2	5	15	20	21	12	7	17
2 (sod)	0	0	12	20	11	1*	Trace*	7
4	0	4	16	22	5	0	0	4

*The readings were made as trace, 5, 10, 15, etc. ppm; the apparent precision shown by these data is due to averaging.

In Table IX are presented the data from the analyses in the Raffensperger cover crop plots at four times during July and August, 1939. The cultivated soil of Plot 1 had a continued and moderate nitrate accumulation. The inferiority of the orchard grass, in this respect, even when nitrate of soda was applied three times is stiriking. Similar analyses of the soil in the middle of the tree squares in which the legumes and grasses were growing showed little or no nitrate accumulation.

TABLE IX—NITRATE CONCENTRATION IN RAFFENSPERGER CULTURAL PLOTS, 1939. (NITRATE EXPRESSED AS P.P.M. IN ONE TO FIVE WATER EXTRACT)

Plot	Depth in Inches	Samples Near Trees Receiving the April Application and 1½ pounds $NaNO_3$ Per Tree at Each of Two Other Applications in 1939			
		July 7	July 20	Aug 8	Aug 24
1* cultivated to mid-July	0 to 6	7	10	8	8
	6 to 12	Trace	0	10	Trace**
2 (cultivated) May reseeding	0 to 6	16	18	15	14
	6 to 12	Trace	4	8	15
2 (sod) mixed legumes	0 to 6	13	18	16	14
	6 to 12	4	3	2	18
3 (legume sod)	0 to 6	22	17	8	8
	6 to 12	4	3	6	7
4 (orchard grass sod)	0 to 6	9	14	4	1**
	6 to 12	3	3	2	1

*Received only the April nitrate application.

**Amounts stated are means of four composites of six cores each. The readings were made as trace, 5, 10, 15, ppm, etc. The indicated precision is due to averaging.

On a separate area, where frequent fertilization kept the nitrate content of an orchard grass plot above 20 ppm, peach size and quality were not improved over that of Plot 4 represented in Table IX. In

1939, soil moisture was limiting peach production and variations in the nitrate level were not reflected in tree performance. This was also true in 1941 and 1943.

Table X shows that in 1940 two applications of nitrate of soda were inadequate to maintain an accumulation of nitrates during the growing period in Plots 2, 3, and 4. Here, Plot 2 cultivated, had a higher accumulation of nitrates in August and September than Plots 2 sod, 3 or 4 which had less cultivation.

TABLE X—SOIL NITRATE ANALYSES. RAFFENSPERGER CULTURAL PLOTS 1940. VALUES SHOWN ARE PPM NO_3 IN A 1 TO 5 SOIL WATER EXTRACT

Depth of Sampling	June 20	July 8	July 23	Aug 13	Sep 12
		Plot 1			
0 to 6	—	20*	20	30	0
6 to 12	15	15	12	20	15
		Plot 2 (Cultivated)			
0 to 6	—	—	7	30	—
6 to 12	—	—	10	22	15
		Plot 2 (Sod)			
0 to 6	Trace	0	8	Trace	Trace
6 to 12	Trace	0	15	0	10
		Plot 3			
0 to 6	2	0	10	17	Trace
6 to 12	0	0	12	10	2
		Plot 4			
0 to 6	2	0	20	17	0
6 to 12	0	0	25	17	0

*Summer application of nitrate of soda July 9 to Plots 2, 3, and 4.

Certainly, the less cultivated plots, those with the more continuous cover, had the least nitrate accumulation. Plot 3, a legume sod plot, usually showed a higher nitrate accumulation than Plot 4, in orchard grass (see Table VIII).

SOIL AGGREGATION AND SLAKING

The extent to which water-stable aggregation and permeability to water are affected by soil management practices is important.

Table XI shows the results of the wet sieving of the 0 to 1½-inch layer of the plots in June 1939. The water stable aggregates greater than 60 mesh were pestled in normal Na_2CO_3. After a week, the material was separated through a 200 mesh screen. This permits an

TABLE XI—SOIL AGGREGATION IN RAFFENSPERGER PEACH CULTURAL PLOTS, 0 TO 1½ INCH LAYER, JUNE 1939

Plot	Water Stable Particles as a Weight Percentage of the Total Sample					Grams of Soil <200 Mesh Existing as Aggregates >60 Mesh
	10 Mesh	10 to 20 Mesh	20 to 40 Mesh	40 to 60 Mesh	Total	
1	6.7*	8.4	5.2	4.8	25.1	6 3
2 (sod)	14.9	8.4	5.8	5.5	34.6	19.0
3	19.4	10.9	8.2	8.2	46.7	18.8

*Figures given are means of two determinations on samples of 100 grs. each.

estimation of the clay, silt, and a portion of the very fine sand which is aggregated and not easily dispersed to form a crust.

The relation between the data of the last two columns shows that difference in the amounts of coarse sand and gravel can make wet sieving data misleading. Data obtained in July 1939 showed that in Plot 3, of the total soil sample, 4.3 per cent was material less than 200 mesh and aggregated into water stable particles coarser than 20 mesh; for Plot 1 this was 1.0 per cent.

Because slaking of the surface soil formed a crust which was partly responsible for observed differences in runoff, estimations of the slaking tendency were made in 1940, 1941, and 1943.

For this determination the apparatus pictured in Fig. 13 was de-

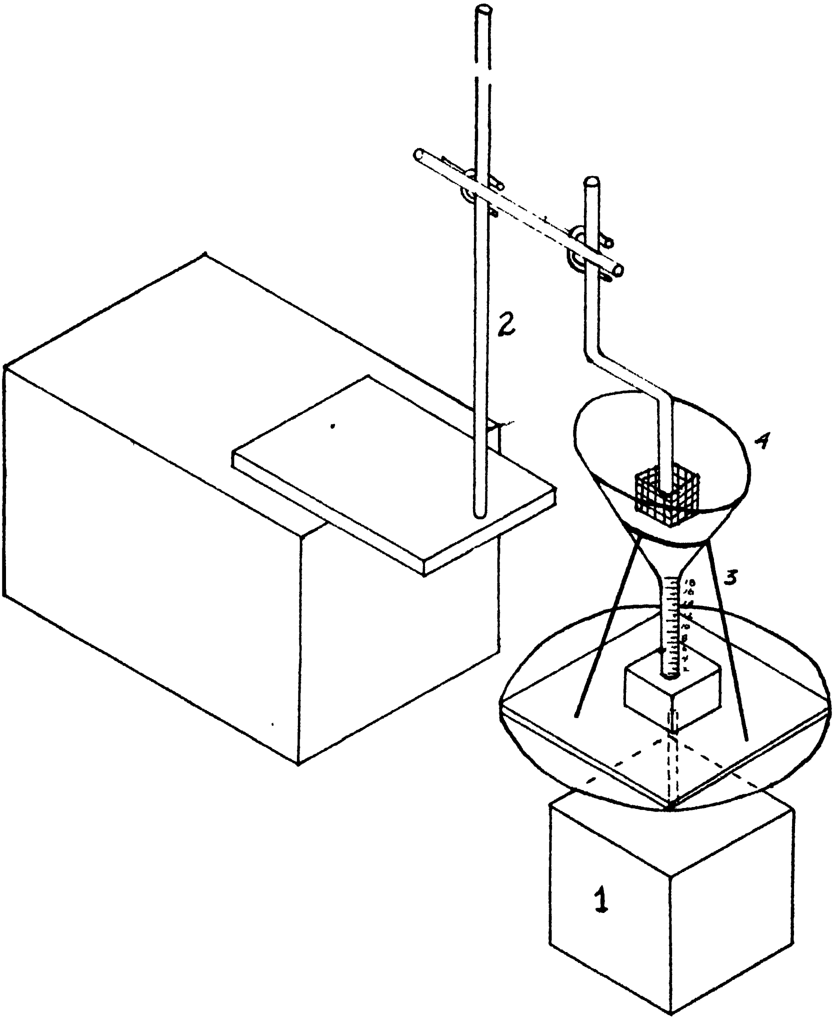

Fig. 13. Soil slaking apparatus.

vised. A 10- to 13-gram clump of air dried soil was placed in the three-mesh hardware cloth basket. About 900 cc of water at 19 degrees C were placed in the stoppered funnel, the stem of which was calibrated in cc as indicated. The phonograph motor was started and the tripod and funnel of water revolved at 60 rpm. Then the basket with the soil clump was lowered below the water surface. Estimations of the volume of slaked soil were made at intervals of 10, 20, 30, 45 and 60 seconds, and 2, 3, 4, 5 and 6 minutes. After 6 minutes, the motor was stopped and the soil remaining in the basket was then stirred through the basket with a stirring rod. The total volume of the soil in the funnel neck was recorded. The volume of soil slaked at the various time intervals was then calculated to a percentage of the total soil volume. Usually, 20 clumps per treatment, or sampling depth, were studied in this manner.

Fig. 14 presents some of the 1941 data and shows the course of the slaking over the 6-minute period of observation. Table XII presents these and other data in more detail. In 1941, Plot 2 (cultivated) and Plot 3 were cultivated in the spring and seeded on June 21. Soil samples were taken 3 months after the last cultivation. In 1943, these two plots were seeded on August 3 and sampled in September. The greater soil slaking with the more prolonged tillage and later seeding is noted. The range is great; but the lower limits are, for each treatment, very low. Treatment differences are well expressed by the upper limit of the range. Perhaps some cover crop residue, or root, or insect channel represents a point of good structure development in all the plots; likewise there may be points or locations where structure is not water-

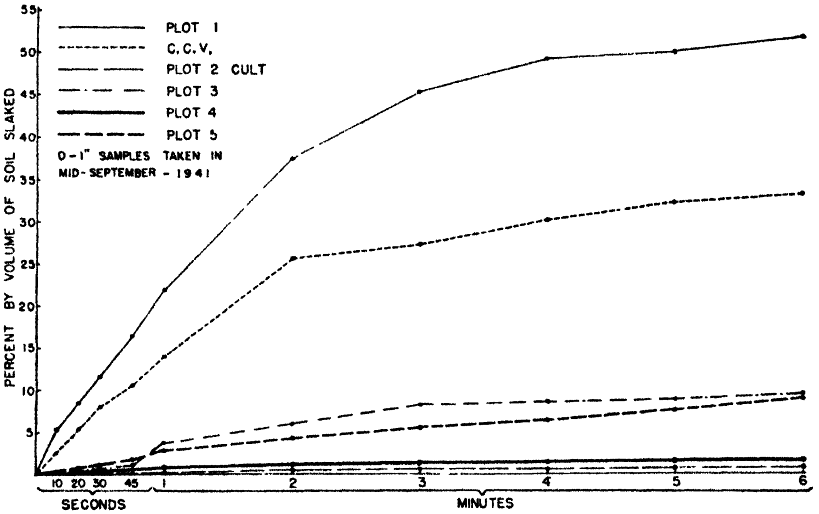

FIG. 14. Slaking of surface soil under various degrees of tillage — Raffensperger Orchard.

TABLE XII—Soil Slaking in Raffensperger Cultural Plots. September 1941 and September 1943

Treatment	Per Cent by Volume of Soil Slaked at Six Minutes			
	0 to 1 Inch Depth		1 to 3 Inch Depth	
	Mean*	Range	Mean*	Range
	Plot 1†			
Sudan grass	52** 72	10–86 27–100	36 61	14–71 10–100
	Plot 1A†			
Crimson clover and vetch	33 13	1–92 3–41	21 25	1–76 3–55
	Plot 2			
Alternate row cultivated	1	0–10	2	1–8
Cultivated row	53	12–100	24	3–86
	Plot 2			
Alternate row cultivated	ND	———	ND	———
Sod row	3.8	0.5 15	8.5	0.5 28
	Plot 3			
Trashy cultivated legume sod	10 37	1–65 15–78	ND 11.3	ND 0.5–43
	Plot 4			
Trashy cultivated orchard grass	2	0–4	2	0 4
Orchard grass sod	1	0 24	1	0 13

*Mean of 20 clumps.

**Top figures are for 1941, bottom figures are for 1943. Figures for Plot 4 and orchard grass sod are for 1941 only.

†For 1 and 1A (0–1 inch) difference is highly significant; for all other treatments the least significant difference is 5.6 at P =0.05.

stable. Winterkorn (12) has presented a recent discussion of soil slaking.

Table XIII is self explanatory. It shows that the subsurface soil at 3 to 6 inches slakes more than the surface soil at 0 to 3 inches. That is the relationship observed in the Raffensperger plots in 1940 when samples were taken at 0 to 3-inch and 3 to 6-inch depths.

In almost every instance the high degree of slaking was associated with either a low amount of soil cover, recent cultivation, or a compact

TABLE XIII—Soil Slaking in Hagerstown Clay Loam, Omwake and Oliver Orchard. June 1940

Treatment	Per Cent by Volume of Soil Slaked After 6 Minutes			
	0 to 3 Inch Depth		3 to 6 Inch Depth	
	Mean*	Range	Mean	Range
Cornfield (rotation)	19	2–49	8**	2–20
Cloverfield (rotation)	3	1–10	18	1–63
20-Year sod orchard	1	0–5	19	0–49
40-Year sod orchard	0.6	0–2	8	0–13

*10 clumps for each mean.

**This corn subsurface was clover surface soil at plowing 3 months prior to sampling.

soil. When water is revolved around the slaking clump, small soil particles are strung like beads along the cover crop roots. These roots are not essential to a low degree of slaking because any one of the mulches is as effective in bringing aggregation about as are the treatments on Plot 3 or 4.

At the Walker Brothers orchard there was an opportunity to study the influence of three tillage practices on soil slaking. On all three areas crimson clover and vetch were seeded in July of 1941; the surface inch of soil was sampled in July 1942. On the area not tilled since seeding, the mean soil slaking was 6 per cent; where a seedbed was prepared in May 1942 and the weeds trashily cultivated in July, it was 32 per cent; where there was trashy cultivation in May and in July 1942, the soil slaking was 9 per cent. This emphasizes that the naming of any one cover crop does not define the soil management practice; the time, kind, and number of cultivations must be taken into consideration.

SUMMARY AND CONCLUSIONS

The major portion of this study was conducted on Penn shale loam which is imperfectly drained, less than 3 feet deep, and erodible. The use of perennial covers in a young peach orchard on this soil even when checked by cultivation has seriously depressed tree growth, or total length of bearing wood, and thus reduced the yields when compared with Plot 1 or 1A in which cover competition was less.

In periods of drought, especially in 1939, the trees in the more continuous or perennial covers made little growth and produced small peaches. In high rainfall seasons the trees in these heavy sods grew and yielded well.

With available soil moisture, sods can seriously reduce peach tree growth by their competition for nitrogen. When both soil moisture and nitrogen were available, the cover crop growth had much less effect on peach tree growth or yield.

In the selection of any soil management system, the intensity, duration, and time of the competition for soil moisture and nitrogen to which it subjects the peach tree must be considered.

The mulching experiment has tended to confirm this emphasis on time and amount of cover crop competition. With the applied mulches, soil moisture had not been reduced to the wilting percentage in 1939–1942. Peach response was well correlated with influence of the mulches on the nitrogen content of the soil.

With deep soil and mature peach trees, perennial covers when carefully controlled by frequent, light diskings and split applications of nitrogen have been satisfactory, but are still questionable because of the danger of severe droughts. The use of such covers offers an excellent opportunity for maintenance of soil fertility.

Mulching, trashy or clean cultivation, spacing of the sod as in alternate row cultivation, or mowing, are means of reducing the loss of soil water by reducing the amount of growing cover.

Nitrogen fertilizers, legume covers, trashy or clean cultivation or mulching with manure or straw and nitrogen are means of maintaining a more favorable supply of available nitrogen than that in unfertilized sod.

Trashy cultivation of a nitrogen-fertilized continuous cover by which part of the growing cover is killed, but left on the surface as a mulch is an effective means of reducing cover competition without the reduction of soil aggregation or increase in the susceptibility to runoff and erosion obtained by clean cultivation. The management of winter legumes as in Plot 1A is a means of increasing the volume of cover with few of the depressing effects of continuous covers.

The study indicates the need to adapt soil management practices to the soil, tree age, and seasonal rainfall.

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Second Report on the Effects of Cover Crops in a Peach Orchard

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AN investigation was started at the Plant Industry Station, Beltsville, Maryland, in the spring of 1932 to determine the effects of certain legume sods and cover crops on the growth and fruitfulness of peach trees. At that time there was an evident need for a re-evaluation of cultural practices for peaches. There was a need for the determination of the effects of several methods of soil management in which the amount of cultivation might be reduced over that practiced formerly. For example, it was once considered good practice to cultivate the peach orchard thoroughly and often during the growing season. One object of the experiment reported here was to evaluate the principal factors, such as moisture and nitrogen, that were concerned in several different soil-management systems. The influence of these management systems on the growth of the trees and the size and yield of fruit over a long period was of special significance.

A report on this same experiment has been made previously with reference to some of the effects of these cultural treatments on the young peach trees (8). It was found that tree growth was seriously affected in the legume sod plots during periods of moisture shortage. The purpose of this second paper is to report the effects of these same treatments on the growth and fruit production of these trees to 12 years of age. The emphasis in this report is placed on the analysis and interpretation of the results with mature trees, especially in comparison with those obtained in the case of the young trees.

Most of the earlier investigations on soil-management problems in orchards were concerned with fruits other than the peach (2, 11, 17, and others). McCue (18), however, working with peaches in Delaware, concluded that the cowpea was one of the best cover crops for peaches and the soybean ranked next. Since the starting in 1932 of the experiment reported here, the results of several experiments on this general problem have been reported. These have been conducted on various soil types and under different soil-moisture conditions. The effectiveness of sods in controlling water run-off and soil erosion in orchards has been well demonstrated recently (1, 5, 6, 9, 16, 19, and 20). Although young peach trees usually make least growth in sod (4, 8, 10, 13, 14), there has been a recent tendency to grow peaches with as little cultivation as practicable (3, 12, 14). Since previous cover-crop and sod tests for peach orchards have been largely in relation to young orchards, more information is needed on the effects of continuous covers on mature peach trees.

SOIL MANAGEMENT TREATMENTS

The treatments used in this test followed those given in some detail in the first report and are repeated briefly here. The trees were of the Elberta variety and were grown in Sassafras gravelly loam soil. Each plot was composed of a row of approximately 21 trees and each treatment described here was replicated once; thus there were two plots of each treatment. The seven treatments consisted of summer cover crops of soybeans and of buckwheat; legume sods of Korean lespedeza, of *Lespedeza sericea*, and of biennial sweet clover; cultivation during the summer; and cultivation with an annual application of approximately 5 tons of manure per acre. Each row, or plot, was separated by a guard row (Fig. 1). In the summer cultivation treatments the cultivation was only to remove weeds and averaged two to three diskings each season. The summer cover crops were seeded about June 1 and disked about August 15 to September 1, when a winter cover crop of rye and vetch was seeded in all cultivated plots. This was disked down in the spring, when the rye was about 20 inches high, or when just beginning to head. The lespedeza plots were disked once each year in the early spring. The sweet-clover plots were disked following seed formation in each second year. A strip was cultivated along either side of each row in all legume sod treatments during the first 5 years.

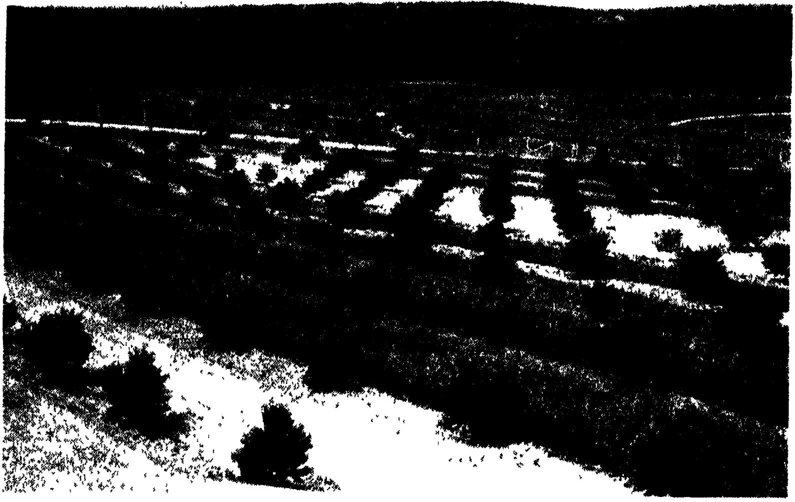

FIG. 1. Peach cover crop treatments in July 1934. The Elberta trees are in their third growing season. Treatments show (left to right) cultivation, sweet clover, Korean lespedeza, cultivation, and buckwheat

Approximately 250 pounds of 5–8–5 fertilizer was drilled in with the seed for the summer as well as for the fall cover crops. The legume sods received the same fertilizer in a single spring application, which amounted to approximately 350 pounds per acre after the fourth year. In addition, nitrate of soda was broadcast under the trees at the rate of ½ pound per tree for the first year, 1 pound for the second, and 3 pounds per tree for the third and remaining years.

TREE TRUNK GROWTH

The mean trunk circumference for each plot was obtained at the end of the 1931 (size at time of planting), 1937, and 1943 growth. These results were used to calculate the mean increase in cross-sectional area per tree in each treatment for three periods: 1932–37, 1938–43, and the entire test period of 1932–43 (Table I).

TABLE I—TRUNK GROWTH, YIELD, AND FRUIT SIZE INDEX OF ELBERTA PEACHES UNDER DIFFERENT SOIL MANAGEMENT SYSTEMS

Plots	Treatment	Tree Trunk Growth			Yield Mean Pounds Per Tree Per Year 1939–42	Fruit Size Index Mean Number Per Pound 1939–42**
		Increase in Cross-section Area (Cm²)				
		1932–37	1937–43	1932–43		
5 and 34	Manure	125.8	189.2	315.0	345.75	3.617
7 and 27	Cultivation	102.1	158.7	260.8	232.62	4.050
9 and 25	Korean lespedeza	64.6	117.5	182.1	136.13	4.417
11 and 23	Sweet Clover	62.4	107.7	170.1	130.63	4.167
13 and 19	Soybeans	89.4	148.8	238.2	197.63	4.033
15 and 29	Buckwheat	81.4	157.3	238.7	194.25	4.150
31 and 32	*Lespedeza sericea*	64.2	128.3	192.5	134.50	3.983
		D. R.* 19:1 = 13.376 99:1 = 19.790	D. R. 19:1 = 41.506	D. R. 19:1 = 47.402 99:1 = 70.130	D. R. 19:1 = 15.25 99:1 = 20.57	D. R. 19:1 = 0.216 99:1 = 0.294

*Difference required for significance at the two levels indicated.
**No record of fruit size in 1941.

Trunk Growth 1932–37:—This period of growth includes the first 6 years of treatments. By use of analysis of variance it was found that the mean increase in trunk cross-sectional area for 1932–37 showed significant differences at the 99: 1 level. The essential results obtained in this analysis of trunk increase in cross-sectional area (cm²) for 1932–37 are given (Table I). The difference required for significance between the means was found to be 13.376 at the 19: 1 level and 19.790 at the 99: 1 level (Table I). On this basis the significant differences in trunk area increase between treatments were:

19: 1 level:

1. Manure > (is greater than) all other treatments
2. Cultivation > all other treatments except manure (less than manure) and soybeans (no significant difference)
3. Soybeans > Korean lespedeza, sweet clover, or *Lespedeza sericea*
4. Buckwheat > Korean lespedeza, sweet clover, or *Lespedeza sericea*

99: 1 level:

Same as 19: 1 level, except No. 4; buckwheat was not significantly different from the sod plots.

Trunk Growth 1937–43:—During this period of growth of the older trees (sixth to twelfth year) there was more variation between trees and plots of the same treatment than during the years 1932–37, when the trees were 1 to 6 years of age. Thus a greater difference between treatments was required for significance. Although there was considerable difference between the mean increases of most treatments

(Table I), these means of the older trees failed to show significance at the 99: 1 level. They did show significance, however, at the 19: 1 level, which indicated some *probable* significant differences (Column 4, Table I).

The difference between the means required for significance at the 19: 1 level was 41.506 (Table I). Thus the only differences between the means of the treatments that were shown as significant at this level were:

Manure > Korean lespedeza, sweet clover, or *Lespedeza sericea*
Cultivation > sweet clover

The lack of difference between many of the treatments when the trees were relatively mature, was probably because the tree and plot replicates varied more in the use of the older trees, and accordingly relatively greater differences between means were required for significant difference. Another important reason is that there was actually less difference between certain of the treatments with mature trees. For example, in these mature trees the mean increase in trunk area for the plots receiving the summer cover crops of soybeans and buckwheat was actually very near the same as that for the clean cultivation. The differences were obviously nonsignificant. From the results obtained during the early years of these tests it was evident that there was considerable competition between the trees and the cover crops (8). As the peach trees became larger the cover crops of soybeans and buckwheat grew less vigorously. This has resulted in less competition between cover crops and trees. Furthermore, as the trees grew older the roots became more extensive and the trees were probably less affected by reduced moisture in the upper horizon.

Trunk Growth Throughout the Test Period, 1932–43:—When the entire 12 years of trunk growth of the trees are considered as a whole, the results follow the same trend, but differences between treatments were not so striking as during the early years of the tests (Table I). An analysis of variance for the total increase in cross-sectional area of the tree trunk showed that the means, on an average, were significant from each other at odds of 19: 1.

The significant differences between treatments, as indicated by the means, were as follows:

19: 1 level:
  Manure > all other treatments
  Cultivation > Korean lespedeza, sweet clover, or *Lespedeza sericea*
  Soybeans and buckwheat > Korean lespedeza or sweet clover
99: 1 level:
  Manure > all others except cultivation
  Cultivation > Korean lespedeza or sweet clover

The tree trunk growth in the manure treatment apparently has been superior to that of any other treatment since the treatments started. This has probably been due partly to the potassium added by the manure, since it has been found that potassium is deficient in this soil (7). Furthermore, the nitrogen added by the manure probably was responsible for some of the increased growth of trees in this treatment. The 5 tons of manure per acre probably added at least 35 pounds of nitrogen, 10 pounds of phosphoric acid, 30 pounds of potash, and small amounts of "minor" or "trace" elements. Thus the equivalent of approximately 210 pounds of nitrate of soda and 60 pounds of muriate of potash per acre was added per year to the manure plots in the manure and is in addition to the nitrogen and potassium applied to the other soil-management treatments. The phosphorus added in the manure may have been in its value as a mulch on the soil.

Considering the total growth to 12 years of age, the cultivation treatment seems to have given larger trees than any of the legume sod treatments. The superiority, however, of cultivation over the soybean and the buckwheat treatments was not so great, and the differences are not statistically significant (Table I). The soybean and the buckwheat plots gave practically the same increase in trunk size. These two treatments probably (odds of 19: 1) produced larger tree trunks than either Korean lespedeza or sweet clover, but not significantly larger than the *Lespedeza sericea* treatment (Table I). Although there was considerably greater increase in the mean trunk area in both the soybean and the buckwheat treatments over the *Lespedeza sericea* treatment (Table I), the variability of the trees within the treatments caused them to show no statistical significance.

YIELDS OF FRUIT

The mean yields of fruit per tree for each plot in the soil-management treatments were obtained each season. The yields for 1936, which were characteristic of the young trees, have already been reported (8). Of special concern in this report are the yields of fruit from mature trees grown under the different cultural treatments; hence the yields are given for the 4-year period 1939–42, or eighth to eleventh years, inclusive. This 4-year period was selected because it represented a continuous series of full crops when serious adverse conditions such as frosts failed to affect the crop. The mean yield per tree for each of the seven treatments was calculated for each year, and from this was determined the mean yield per tree per year for each treatment for the entire 4-year period (Table I). There were striking differences between the yield obtained from several of the treatments, and these in general followed the differences described for the trunk area increases (Table I). The difference between these mean yields (Table I) required for significance at the 19: 1 level was 15.25 pounds, whereas at the 99: 1 level it was 20.57 pounds. Therefore the treatments showing significant differences were:

99: 1 (same at 19: 1)
  Manure > all other treatments
  Cultivation > all treatments except manure (less than manure)
  Soybeans and buckwheat > sweet clover, Korean lespedeza, or L. sericea

Thus there were four definite treatment classes based on yields. In order of highest to lowest yields, they were: (a) Manure, (b) cultivation, (c) soybeans and buckwheat, and (d) Korean lespedeza, sweet clover, and L. sericea (Table I).

A fairly good crop of fruit was produced on all plots during all 4 consecutive years considered here (Table II). In order to determine whether there was any difference in yields due to seasons, all plots were considered together for each of the four years 1939–42. It was found that each year the yields were different, except that there was no significant difference between those of 1941 and 1942. The lowest yield was produced in 1940 and the next lowest in 1939, whereas 1941 and 1942 yielded the most fruit in all plots or treatments (Table II). These total yields for each year were dependent on weather for the season, and probably more on amount of rainfall than on any other factor.

TABLE II—YIELD AND FRUIT SIZE INDEX OF PEACHES IN ALL TREATMENTS FOR EACH OF FOUR YEARS

Year	Yield Pounds Per Tree	Size Index Number Per Pound
1939	179.92	4 036
1940	158.64	4.743
1941	226.71	—
1942	217 78	3.400
	Difference Required—	Difference Required—
	19 1 =11.53	19:1 =0.141
	99:1 =15 55	99:1 =0.193

SIZE OF FRUIT

In order to determine the relative fruit sizes in the different soil-management treatments, the number of fruits per bushel of 45 pounds was determined on 2 bushels from each tree. From this the mean number per bushel for each row or plot was calculated. The mean number of fruits per pound for each treatment for each year was then determined. The fruit sizes on the mature trees for 3 years (1939, 1940, and 1942) were used in this analysis (Table I). The fruits from the Korean lespedeza treatment were probably (odds of 19: 1) smaller than those from any other treatment, and significantly (odds of 99: 1) smaller than those from manure, cultivation, soybean, and lespedeza sericea treatments. The fruits from the manure treatment were larger than those from any other treatment (odds of 99: 1). The other differences in average fruit size are evidently not significant (Table I). It is noteworthy that the relatively large size in the manure treatment was associated with the high yield here, but that this relationship is not seen with the other treatments. Evidently factors other than those determining relative size and yield of trees were responsible for the fruit size. For example, the Korean lespedeza and lespedeza sericea seem to have had about the same effect on tree trunk growth and yield, but the Korean lespedeza reduced the fruit size more.

The fruit sizes for all treatments were considered together in order to determine the differences in fruit size due to season or year (Table II). In 1939 the number of fruits per pound in all treatments was 4.036; in 1940 it was 4.743; and in 1942 it was 3.400 (Table II). Thus it was found that the smallest fruits were produced in 1940, when the yield was also the smallest, and the largest fruits were obtained in 1942 with the largest yield. The differences in fruit size for the different years were due to variation in growing seasons, especially in amount and time of rainfall each season.

SUMMARY AND CONCLUSIONS

The yield of fruit in different soil management treatments has been closely related to trunk growth of the peach trees. This relationship was especially striking when the yields of the mature trees (1939–42) were compared with the trunk growth of the young trees (1932–37).

The trunk increase, yield, and fruit size have all been outstanding in the manure treatment. There were probably two principal reasons for this, although there might have been others that were not evident. Some of the potassium as well as the nitrogen added by the manure was in addition to the amounts applied to the trees in the other treatments. In the studies described here no attempt was made to determine the influence of different amounts of nitrogen or potassium on the growth and yields of the trees under the various soil-management systems.

Although there were no significant differences in trunk growth of the mature trees (1938–43) under cultivation, soybeans, and buckwheat, the fruit yield was highest under cultivation. This increased yield under cultivation may have been due largely to the superior growth of the young cultivated trees (1932–37). Probably the young trees in cultivation grew more than those in cover crops, mostly because of the greater soil-moisture supply (8). The trunk growth of the mature trees seemed to be reduced less by the crops of lespedeza than was the growth of the young trees. This may have been partly due to the more extensive rooting of the mature trees and also to the greater variation within treatments in the case of the mature trees.

The Korean lespedeza treatment produced the smallest fruits, and the manure treatment resulted in the largest. In any given treatment, the larger the crop in any one year the larger the size of fruit. Since all the trees were uniformly thinned each year, the variation between the different years resulted largely from fruit size.

Under the conditions of these tests there was some, but not serious, sheet erosion in the cultivation and manure plots. All the plots with summer cover crops, including those with soybeans and buckwheat, seemed free from erosion. The sod covers of sweet clover, Korean lespedeza, and lespedeza sericea prevented erosion quite effectively, but the tree growth and yields were much lower than in the soybean and buckwheat plots (Fig. 2). This was the result largely of competition between the sod crops and the trees for soil moisture, especially during drought periods (8), and perhaps partly to competition for available nitrogen, which has been found responsible under certain conditions (2, 11, 12, 15, 17).

It may be concluded that under the conditions of this test, sod cover crops of lespedeza and sweet clover have not been satisfactory for mature peach trees, especially from the standpoint of fruit yields.

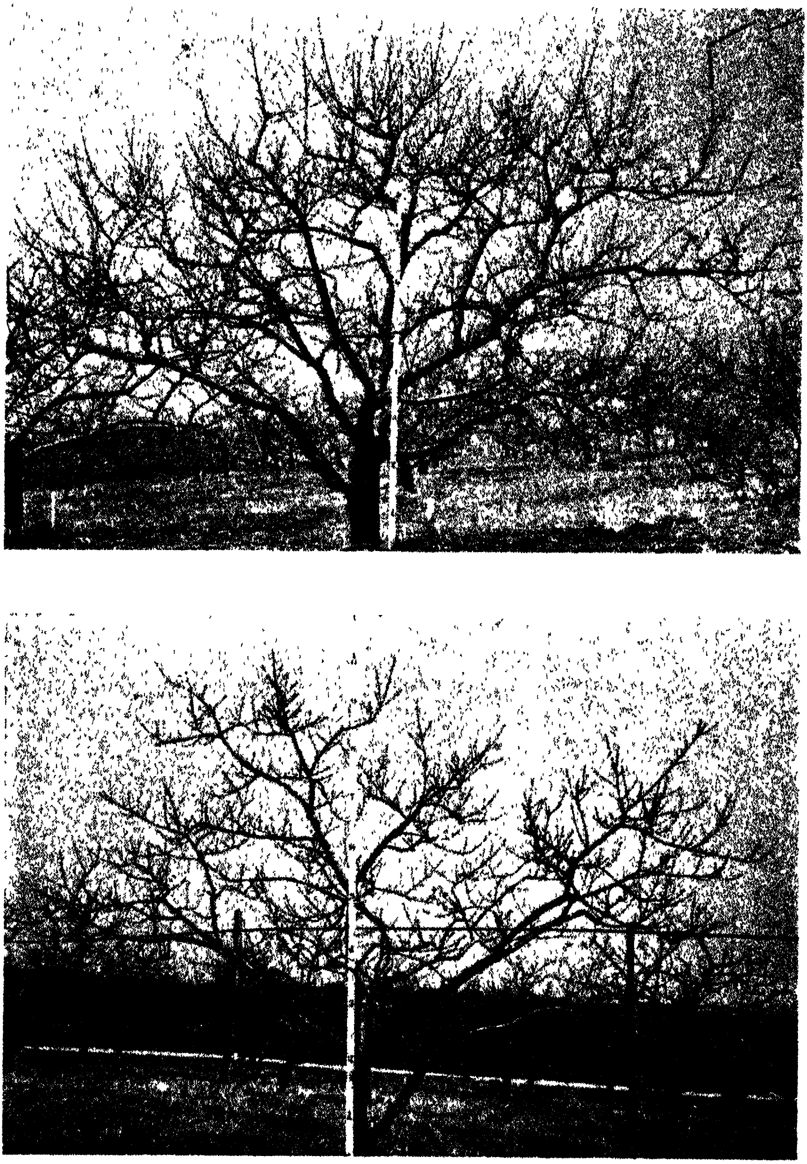

Fig. 2. Twelve-year-old Elberta peach trees. Above, tree grown in sweet-clover treatment; below, tree grown in soybean plot. Both photographed before annual pruning.

A summary of the analysis of variance of the means given (Tables I and II) may be helpful in the interpretation of the results.

1. Trunk growth for 1932-37:

Source of Variation	Degrees of freedom	Mean square	F
Total	13	—	—
Treatment	6	1115.07	34.85*
Error	7	31.994	—

*Significant at 99:1 level.

2. Trunk growth for 1938-43:

Source of variation	Degrees of freedom	Mean square	F
Total	13	—	—
Treatment	6	1573.52	5.107*
Error	7	308.13	—

*Significant at 19:1 level.

3. Trunk growth for 1932-43:

Source of variation	Degrees of freedom	Mean square	F
Total	13	—	—
Treatment	6	5188.39	12.92*
Error	7	401.70	—

*Significant at 99:1 level.

4. Yields (pounds per tree) for 1939-42:

Source of variation	Degrees of freedom	Mean square	F
Total	55	—	—
Treatment	6	47,224.0	212.9*
Year	3	14,334.0	64.63*
Year ×treatment	18	312.5	1.41
Error	28	221.785	—

*Significant at 99:1 level.

5. Fruit size (number fruits per pound) for 3 years (1939, 1940, 1942)

Source of variation	Degrees of freedom	Mean square	F
Total	41	—	—
Year	2	6.32	195.182*
Treatment	6	0.35	10.65*
Year ×treatment	12	0.0675	2.08
Error	21	0.03238	—

*Significant at 99.1 level.

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Some Effects of Mulches on Soil Properties[1]

By C. A. BOLLER and R. E. STEPHENSON, *Oregon Agricultural Experiment Station, Corvallis, Ore.*

It is now generally recognized that the addition of carbonaceous organic materials to the soil may tie up the available nitrogen supply for a time. Other effects reported are (1) the production of acidic and toxic substances, (2) increase of soil aggregation, and (3) improved nutrition of the crop due to nutrients contributed by the mulch and the conservation of soil moisture. The various effects of different mulching materials have been under study at the Oregon Agricultural Experiment Station for a number of years. This paper is a preliminary report on the effects of various materials on soil reaction, soil fertility, and soil aggregation.

Observations were made and soil samples were taken from mulched plots on the Station farm and from the farm of A. B. Sacre of Monmouth, Oregon, who has been mulching raspberries for 10 years.

EFFECT OF MULCHES ON SOIL REACTION

The mulching materials indicated in Table I were applied to Chehalis silty clay loam on the Station farm in the spring of 1944. The sawdust and leaf mulches were 3 inches deep when settled and the straw and hay mulches 6 inches deep.

The pH of the mulching materials and the first, second, and third 2-inch layers of soil beneath the mulches was determined by the glass electrode method in July and in September 1945. There was no significant difference in the readings and only one set of figures is reported.

The data indicate that neither fir nor alder sawdust had any effect upon the pH. The straw, hay, and walnut leaves may have slightly reduced the acidity of the soil next to the mulch. These materials in the process of rotting produced a slight alkalinity, due no doubt to the liberation of bases in the process of decay. The walnut leaves had the greatest effect, extending to the full six inch depth of sampling.

TABLE I—pH OF MULCHES AND UNDERLYING SOIL. (CHEHALIS SILTY CLAY LOAM)

	Mulching Material	0 to 2 inches	2 to 4 inches	4 to 6 inches
Check	—	6.6	6.6	6.5
Fir Sawdust	5.0	6.6	6.6	6.7
Alder Sawdust	6.2	6.8	6.5	6.6
Wheat Straw	7.5	7.6	6.4	6.4
Alfalfa Hay	7.7	7.0	6.6	6.5
Oak Leaves	7.4	6.3	6.4	6.3
Walnut Leaves	8.5	7.9	7.2	6.9

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[1] Published as Technical Paper No. 490 with the approval of the Director of the Oregon Agricultural Experiment Station. Contribution of the Departments of Horticulture and Soils.

EFFECTS OF MULCHES ON SOIL FERTILITY AND AGGREGATION

A 5-acre planting of Newburgh and Taylor raspberries on the Sacre farm has been handled as follows:

Twenty-five tons of cow manure per acre was applied before planting and a top dressing of manure was applied the first year after planting. Thereafter the mulch was depended upon to maintain the fertility. Part of the planting was mulched solidly and part has unmulched strips down the centers of the rows to facilitate pruning and harvesting operations. An initial application of 15 to 20 tons of ryegrass or fescue straw per acre was required to build up mulch strips 5 feet wide and 2 feet deep (16 to 18 inches when settled), and about one-third of that amount was added annually to maintain the depth.

Soil samples were taken from this planting and adjoining land on November 30, 1945. Analyses are reported in Table II. The analytical methods used were described in a previous report (1).

TABLE II—EFFECT OF STRAW MULCH ON SOIL FERTILITY AND AGGREGATION. (SACRE FARM, WILLAMETTE SILT LOAM)

Soil Treatment and Depth of Sampling	Aggregation, Granules> 1.0mm (Per Cent)	Organic Matter (Per Cent)	Nitrates After 5 Weeks Incubation (Ppm)	Soluble P (Ppm)	Soluble K (Ppm)	Soluble Ca (Ppm)
Mulched 10 years 0–6 inches..	30.4	5.5	18	204	1063	2200
Mulched 5 years 0–6 inches	12.4	5.4	38	261	852	2760
Unmulched strip between rows, 0–6 inches	3.3	5.3	11	192	634	2190
Adjoining unmulched orchard (20 years old, cultivated in summer), 0–6 inches. .	2.2	4.2	8	238	566	2690
Adjoining unmulched strawberry Planting (25 tons manure per acre applied in spring), 0–6 inches	4.7	3.8	10	259	404	2860
Mulched 5 years, 6–12 inches	9.8	4.8	20	232	429	2720
Adjoining unmulched orchard 6–12 inches.	3.0	3.8	8	172	435	2450

Soil aggregation, or granulation, was measured by the wet sieve method showing the percentage of granules having a diameter larger than 1 millimeter. The mulch had a marked effect on aggregation, even the 6 to 12-inch depth showing considerable increase in granulation. The difference in aggregation was easily discernible in the field. The cultivated soil in the orchard broke up in chunks and had a very noticeable tillage pan, while the soil under the mulch broke apart in crumbs and granules and had no tillage pan. The fact that the aggregation was much greater under the 10-year mulch than under the 5-year mulch indicates that the change was probably slow.

The chemical differences were less pronounced. The organic matter content of the soil under the mulch was higher than that of unmulched areas. The capacity of the soil to produce nitrate was somewhat increased by the mulch and roughly followed the increase in organic matter. Soluble potassium was increased in the first 6 inches. Soluble phosphorus and calcium were little affected.

Yields from the entire planting, consisting of plants from 2 to 11 years old, have ranged from 3 to 5½ tons per acre in recent years (the lower yields were in years of serious loss from sunburn). There are no unmulched plots to use as checks, but comparable plantings receiving ordinary care usually produce 2 to 4 tons per acre. The mulch is reported to have considerably prolonged the picking season.

The soil differences and the superior performance of this planting are not conclusive evidence of the value of mulching. They suggest, however, that controlled experiments are warranted and that long periods are necessary to get the full effects of the mulch.

SUMMARY

The sawdust mulches had not changed the acidity of the underlying soil at the end of 18 months. Mulches such as straw and walnut leaves decreased the acidity.

A raspberry planting which has been mulched with straw for 10 years has produced high yields. Analyses of soil from this planting and from adjoining land show that the mulch has greatly improved the soil aggregation and slightly improved the organic matter content and fertility.

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Varietal Susceptibility to Boron Deficiency or Excess in Citrus

By A. R. C. Haas, *University of California Citrus Experiment Station, Riverside, Calif.*

The boron content of mature citrus leaves from trees grown in a given soil varies according to the rootstock variety (1). The water-insoluble boron content in the dry matter of such leaves is approximately the same regardless of the rootstock variety. Large differences, however, occur in the water-soluble and the total boron content in these leaves. The marked efficiency therefore of certain rootstock varieties in absorbing boron from the soil solution suggests that these varieties may be less susceptible to boron deficiency when grown under conditions of low boron content in the nutrient medium and more susceptible to boron excess when grown under conditions of high boron concentrations.

Rough lemon, grapefruit, sweet orange and sour orange leafy stem cuttings were rooted in plaster sand in propagation chambers maintained at 75 to 80 degrees C and were then hardened. A cutting of each of these varieties was placed in each of 12 solution cultures, the containers of which consisted of aluminum kettles and cut-off acid carboys, each culture vessel having a capacity of 27 or more liters. The culture solution employed was essentially Hoagland's solution in which the phosphate was greatly reduced and to which the minor elements such as manganese, zinc, and iron were added.

The rooted leafy twig cuttings when placed in the culture solution contained a varying content of boron according to the nature of the rootstock variety. The immobility or fixed accumulations of boron in leaves has been referred to in several investigations although recent studies with citrus have not added support to this view (2). If the accumulated boron originally present in the cuttings at the time of being placed in the culture solutions were immobile then the variations in the boron content of the cuttings of the several varieties could be disregarded. The behavior of the cuttings in the solution cultures containing no added boron and in other control cultures containing boron, was such as to suggest a larger luxury consumption of boron in some varieties than in others, with very little of the boron fixed in the leaves. There is considerable boron in the expressed sap of citrus leaves. Much of the boron in dried citrus leaves is water soluble and much of the water-insoluble boron is soluble in dilute acids.

The solution cultures were begun on February 19, 1945, and on September 29, 1945 many of the leaves of the sour orange cuttings showed advanced stages of vein splitting in the cultures to which no boron was added, whereas no vein splitting occurred in the leaves of rough lemon, grapefruit or sweet orange cuttings growing in the same cultures as those of the sour orange. From the appearance of the cuttings it was obvious that the growth of the rough lemon cuttings was far greater than that of any of the other varieties of cuttings.

There is reason to assume that one rootstock is more resistant to boron deficiency than another. The fresh weights (in grams) of the cuttings in representative cultures to which no boron was added were: rough lemon 159, sweet orange 40, sour orange 23, and grapefruit 20, respectively. When 3 ppm of boron originally was present in the culture solution, the fresh weights (in grams) of cuttings in representative cultures were: rough lemon 143, sweet orange 41, and sour orange 83, respectively.

In the cultures to which no boron was added, after an additional 2 months, the mature leaves of the sweet orange and grapefruit cuttings showed considerable vein splitting while only faint indications were just beginning to become evident in the leaves of the rough lemon cuttings.

When all of the cuttings in a culture to which no boron was added showed boron-deficiency symptoms (vein splitting as shown in Fig. 1, nos. 1, 2, and 3) boron was then added to the culture in toxic concentration (3 to 6 ppm). The leaves of the rough lemon cuttings were the first to show symptoms of injury (Fig. 1, no. 4) from excessive absorption of boron. The excessive boron concentration greatly increased the growth of the sour orange cuttings without showing any symptom other than the faintest tipburn in a few leaves. The effects from the higher boron concentration were more favorable to the growth of the sour orange than to that of the rough lemon cuttings.

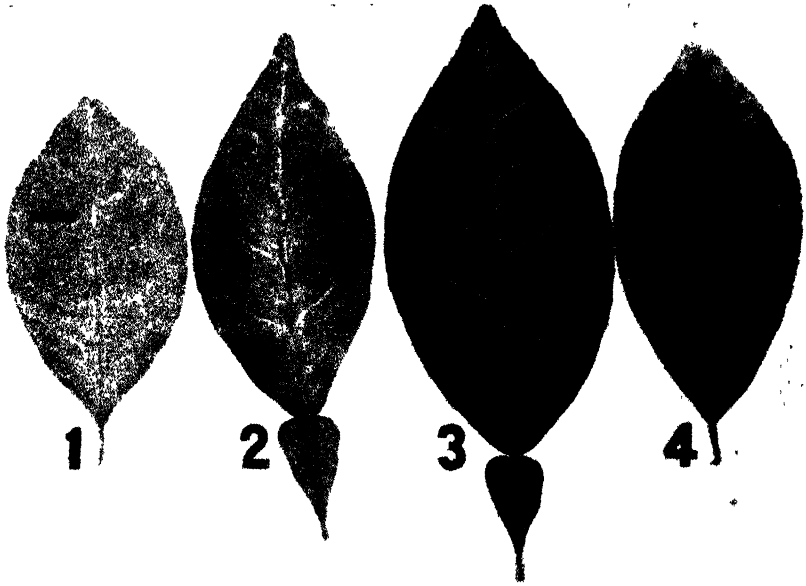

FIG. 1. Symptoms of boron deficiency and excess in rooted citrus leafy twig cuttings grown in solution cultures · No. 1, first indication of boron deficiency in a rough lemon leaf; Nos. 2 and 3, severe vein splitting that resulted from boron deficiency in sour orange leaves, No. 4, first stages of boron excess in a rough lemon leaf.

These results are in harmony with the recent practice,[1] followed by a large citrus company in Florida. The soil of a large acreage planted to orange trees on sour orange rootstock was treated with boron and the trees were sprayed with boron, a total of 52. 5 pounds of borax per acre per year being utilized in these treatments. The trees are reported as having shown great increases in vigor and in vegetative and fruiting activity. This rate of application has since been reduced to 35 pounds per acre per year and may be reduced further. However, there is some hesitation in treating the trees on rough lemon and Cleopatra mandarin rootstocks with the amount of boron that was advantageous and beneficial to sour orange rootstocks.

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[1] Private communication.

CONCLUSION

The rough lemon rootstock because of its more active absorption of boron is less susceptible to a condition of boron deficiency and more susceptible to a condition of boron excess than the sour orange rootstock.

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Unnecessary Irrigation As An Added Expense in the Production of Prunes

By A. H. Hendrickson and F. J. Veihmeyer, *University of California, Davis, Calif.*

Introduction

Readily available soil moisture may be defined as the amount of moisture between the field capacity and the permanent wilting percentage of a soil. A number of studies have shown that if the soil moisture is maintained between these limits, plants do not suffer from lack or water, and may be expected to produce all they can, if not adversely affected by other limiting factors such as lack of fertility, depredations of insects and diseases, lack of suitable pruning and thinning, or unfavorable weather conditions. There still exists, however, the general idea that, if maintaining readily available moisture at all times is good, the addition of more water to keep the soil moisture relatively high in the available range is better. This paper deals with experiments with prune trees, some of which were supplied with readily available moisture at all times (except in certain unavoidable instances described later), some with more water than necessary, and some which were not given quite enough moisture. Whenever the plots were irrigated, the soil was moistened to a depth of six feet, so that the trees either had or had not moisture to the depth occupied by most of the roots. Light irrigations, wetting the soil to a shallow depth, were not used.

The plots consisted of eight French prune trees, surrounded on all sides by guard trees receiving the same irrigation treatment. Plots were replicated three times for two of the treatments and four times for the third. Treatment A was kept at a relatively high moisture content, treatment B was allowed to exhaust the moisture to the permanent wilting percentage before replenishing the supply, while treatment C was irrigated during the early part of the season only; the average date of the final irrigation being July 20. The description of the treatments may be made clearer from the average number of irrigations given each treatment which were: treatment A, 4.5; B, 3.1; and C, 2.2 irrigations. Inasmuch as the irrigations were under the direction of the same man throughout the 13 years herein reported, the average application was very close to 7.5 acre inches per acre for each application. The soil-moisture records for these treatments indicate that in general, the A treatments had readily available moisture at all times, Fig. 1, and that for considerable periods the amount was relatively high in the available range. The B treatments were reduced to about the permanent wilting percentage several times each year, ranging in length from a few days to several weeks during the harvest period, the C treatment, while kept moist in the early part of the season, was reduced to the permanent wilting percentage and remained there for several months in the latter part of the season. Thus, by way of contrast, the B treatment reached the permanent wilting percentage several times for short periods each year, while the C treatment reached this moisture content and remained there for a long period.

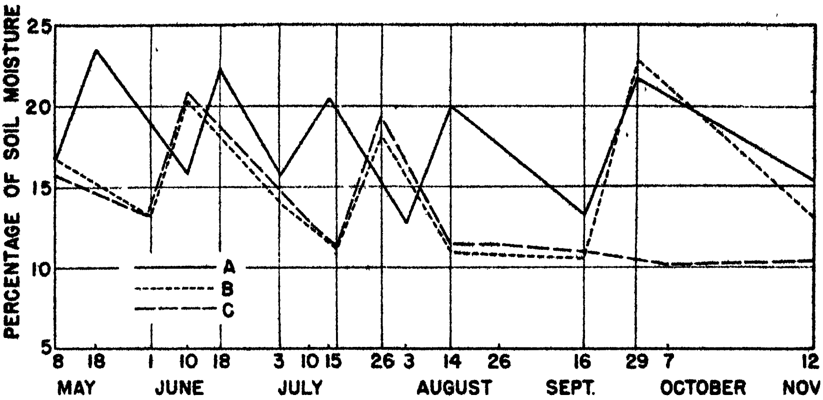

FIG. 1. Soil-moisture contents of the top 3 feet in the orchard during a typical season.

Growth of Trees:—The growth of trees as indicated by the average cross-section areas of the trunks is shown in Fig. 2. It will be noticed that for 2 years the differential irrigation treatment had comparatively little effect on the growth of the trees, and thereafter the trees in the A treatment were the largest, with those of B and C in order. The slopes of the curves indicated that the A treatment is slowly increasing its size over the B, while both A and B are increasing over C somewhat more rapidly. The short periods the trees in treatment B were without readily available moisture probably resulted in smaller trees than in treatment A. The tendency for alternate bearing is indicated by the

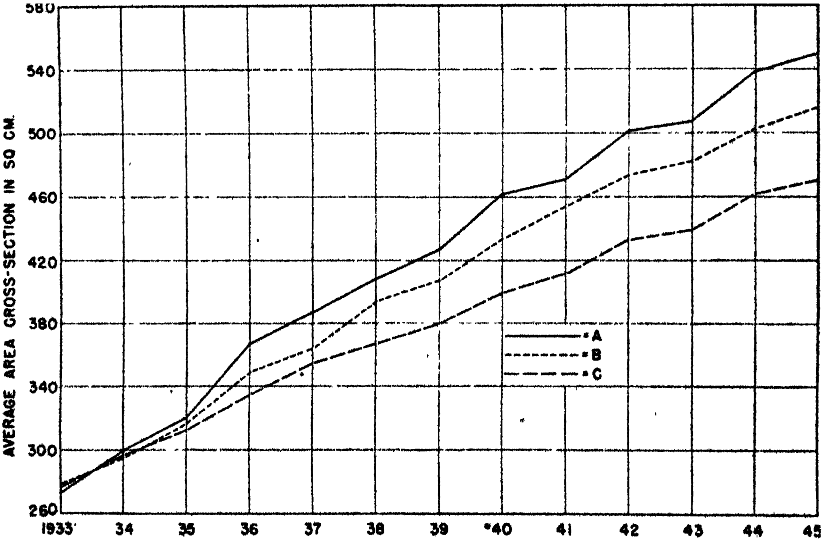

FIG. 2. Average cross-section areas of trunks of prune trees.

rapid or slow increase in cross-section area particularly during the past 5 or 6 years. Although the trees in treatment A are somewhat larger than those in B, as measured by the cross-section areas, the tops of the trees do not show so much difference in size.

Yields:—The average cumulative yields expressed as tons per acre of fresh fruit are shown in Fig. 3. It is apparent that treatments A and B yielded approximately equal crops. All treatments produced substantially equal yields for 6 years after differential irrigation treatments began. In 1939 the yield from treatment C fell below those of A and B, and it has remained there since that time. The quality of the dried product, as measured by specific gravities, and drying ratios, was essentially equal for all three treatments. In sizes, treatment C, in addition to producing less fruit than the other two, produced a slightly smaller proportion of large sizes and a larger proportion of small prunes than either A or B, as discussed later.

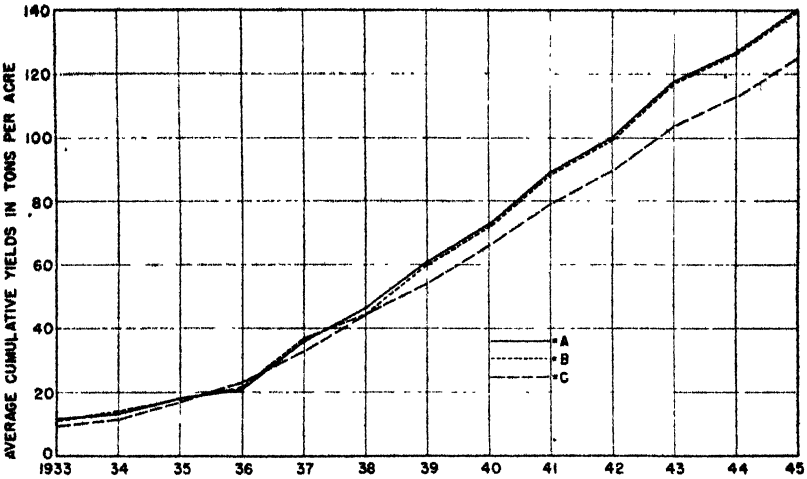

Fig. 3. Average cumulative yields of prune trees.

Further details concerning the yields and production costs are given in Table I. Column 2 gives the average number of irrigations necessary to maintain the soil moisture conditions described in an earlier paragraph. Columns 3, 4, and 5 give the total amounts of water applied, the average yearly amounts, and the average amount for each

TABLE I—Amounts of Water, Costs, and Yields of Prunes During a 13-Year Period

Treatment	Average Number of Irrigations Per Year	Total Amount Water Applied (Acre-Inches)	Average Amount Per Acre Per Year	Average Amount Per Irrigation (Acre-Inches)	Total Weight of Dried Fruit (Tons)	Total Cost of Irrigation (Dollars)	Total Income (Dollars)
A	4.5	445	34.2	7.5	46.9	818.80	7504
B	3.1	315	24.2	7.9	46.6	579.60	7456
C	2.2	220	16.9	7.6	41.0	404.80	6560

irrigation in acre inches per acre. Column 6 gives the average cumulative yields of the dried fruit, and was obtained from Fig. 3 by dividing the figures given for 1945 by the average drying ratio, 3. The total cost of preparing the land for irrigating, water, and the application of the water are given in column 7. The last column gives the gross returns per acre for the 13-year period. Costs of labor and tractor work was figured on 1945 costs. Returns for the entire period were calculated on the basis of the ceiling price for prunes in 1945. While this method of treating costs and returns makes the total higher for both than a true average for the period, it is simply used by way of illustration. In the early years of the experiment, prunes sold for less money, but labor and tractor costs were also less than during the war period.

Inasmuch as prunes are sold on a size basis, the proportion of the various sizes delivered to the packing house frequently has a pronounced effect on the returns. The average percentage of sizes produced are given in Table II.

TABLE II—AVERAGE PERCENTAGE OF SIZES OF PRUNES

Treatment	Large	Medium	Small
A	41.9	35.3	22.8
B	35.5	36.1	28.7
C	31.0	41.7	27.3

From Table I, it will be seen that treatment A returned $48 more per acre than treatment B, but we also find that it cost $239.20 more to irrigate this treatment, showing that the extra water and labor was not a profitable investment. In a similar way treatment B returned $896 more than C, while additional expense for irrigating was only $174.80.

DISCUSSION

The trees in treatment B apparently have produced all they are capable of producing, and the only advantage gained by the trees in treatment A has been a slight increase in size of tree as measured by the cross-section areas. While we ordinarily expect the larger trees to produce the larger crops, this has not been true during a 13-year period. How much longer it will be necessary to produce markedly larger crops in the A treatment is unknown.

The sizes of fruit in the A treatment were not materially increased. This treatment produced about 6 per cent more large fruit and about the same percentage less small fruit than the B treatment. Here again the difference in sizes is not enough to compensate for the extra irrigations involved.

On the other hand treatment C obviously suffered from insufficient irrigation. The total crop was smaller than either A or B and the average percentage of large sizes was also smaller.

The results indicate that refilling the soil reservoir when empty or nearly so is the most economical irrigation practice. In commercial operation, of course, irrigation must be started somewhat before the lower limit is reached in order to cover the entire acreage before the last trees are allowed to suffer very long.

The results of these experiments show that soil moisture is readily available throughout the range between the field capacity and the permanent wilting percentage. If this were not true, treatment A which had soil moisture high in the availability range should have shown some benefits from the extra water supplied throughout the 13 year period.

The results also indicate that trees in soil at the permanent wilting percentage for comparatively short periods are apparently not injured, but that reduction in growth and crops results when they are allowed to suffer for water for long periods.

Except for a small difference in trunk cross-section area, which may have been due to unavoidable dry soil conditions for short periods, there is nothing in these results to indicate a benefit from irrigating more frequently than necessary to keep the soil-moisture content above the permanent wilting percentage.

From the results, too little water may be injurious, while unnecessary water is valueless.

The Apparent Effect of Moisture Supply on Naphthalene Acetic Acid Treatments for Delaying the Drop of McIntosh Apples

By M. B. HOFFMAN and L. J. EDGERTON, *Cornell University, Ithaca, N. Y.*

DURING the 1944 growing season, hot, dry weather prevailed in most of the southern Hudson Valley section of New York State. Rather serious drought conditions developed in many orchards before harvest time. Weather records of the Warwick Station, which is located in one of the areas most effected, showed that the rainfall in May and June was 1 inch less than normal and that only 3.81 inches fell during July and August. Compared with the normal, this represents a total deficit of 6 inches for the 4-month period. No precipitation was recorded by this station from September 1 to 11 inclusive.

McIntosh apples began to drop in this area about September 5. While the size of the fruit in orchards on the deeper soils was fairly satisfactory, the color in general was poor. Growers who used the harvest spray at the beginning of this drop reported, after an interval of about 1 week, that the effect of the treatment on drop control had been negligible.

A test of naphthalene acetic acid for delaying the preharvest drop under these conditions was conducted in a 20-year-old block of McIntosh trees which had received excellent care and were vigorous and uniform. The orchard was located on Dutchess silt loam soil. This type permits the rooting of trees to a depth of 3 feet or more and is regarded as one of the better fruit soils in the Hudson Valley. The treatments were made on September 8. At this time, the trees showed no visible effects of the dry weather. There was no evidence of wilted foliage during the day and the fruit averaged about 2¾ inches which is a desirable commercial size for the variety. The orchard cover, however, was completely killed. Although no samples were taken for moisture determinations, it seemed likely that the wilting point of the soil had been reached to the depth of a foot or more for some time.

Ten trees were included in each treatment. These were selected at random for uniformity of crop, color of foliage and maturity of fruit. After the treatments were applied, all drop apples were cleared from under the trees. Between one and one and one-half boxes of freshly dropped apples were collected from each tree, indicating that the preharvest drop had been in progress for several days. Drop records were started on September 9.

The treatments and the daily accumulative drop from September 9 to the date of harvest are given in Table I. Rain started at noon on September 12 and continued intermittently until midnight, September 14. During this 60-hour period, there was a total precipitation of 5.38 inches which exceeded the entire amount of rainfall from July 1 to September 11 by 1.57 inches.

The weather cleared on the morning of September 15. When the drop records were completed on this date, it was evident that none of

TABLE I—THE COMPARISON OF THE EFFECT OF NAPHTHALENE ACETIC ACID ON THE DROPPING OF McINTOSH APPLES BEFORE AND AFTER HEAVY RAINS WHICH RELIEVED A DROUGHT CONDITION IN THE ORCHARD

Original Treatments Sep 8	Number of Trees	Cumulative Per Cent Drop							Treatment Repeated	Number Trees	Cumulative Per Cent Drop						
		Per Cent of Crop on Trees Sep 8*									Per Cent of Crop on Trees Sep 15						
		Sep 9	Sep 10	Sep 11	Sep 12	Sep 13	Sep 14	Sep 15			Sep 16	Sep 17	Sep 18	Sep 19	Sep 20	Sep 21	Sep 22
Check	10	1.0	2.3	4.4	7.4	9.2	12.3	17.5	None	10	0.4	1.3	3.2	6.1	9.2	10.1	14.3
10 ppm spray	10	1.2	2 7	4.9	8.1	9.3	11.1	15.5	Sep 15	6	0.05	0.1	0.2	0.5	0.8	1 1	1.9
									None	4	0.08	0 2	0.8	2 7	5.7	7.3	11.9
20 ppm spray	10	0.9	2.1	3.7	4 7	6.0	7.6	12.1	Sep 15	6	0.04	0.1	0.2	0.5	0.6	—	—
									None	4	0 09	0.1	0.9	—	—	—	—
30 ppm spray	10	1.2	2 5	4.0	5.2	6.6	8.4	12 9	Sep 15	6	0.02	0.04	0.2	0. 3	0.5	0.6	0.9
									None	4	0.01	0.07	0.3	1.0	2.2	3.1	4.6
0 1 per cent dust	10	1 0	2.2	4.1	6.5	7.4	8.9	13.6	Sep 15	6	0 07	0.1	0.3	0.7	1.3	1.9	2.3
									None	4	0.09	0.2	1.0	2.4	4.2	5.3	—
Temperatures Max.		70	83	87	63	70	75	82			83	82	72	68	80	78	78
Min.		58	42	40	53	55	65	65			57	53	56	56	65	65	51

*Average total yield per tree: 24.2 bushels September 8, 20.7 bushels September 15.

the treatments had been particularly effective in preventing drop during the previous 7-day period. The trees were then carrying an average crop of 20.7 bushels each and it appeared that the harvest could not be attempted before another week. All treatments were repeated at this time on six of the ten trees in each group since it has been demonstrated (1) that the effect of a single application of this chemical on McIntosh drop may be lost 7 to 8 days after the application. The remaining 4 trees in each of these groups were left without duplicate treatments in order to observe any after rain effects from the initial applications made September 8.

Following the rain, there was a reduced rate of drop from the check trees for several days. This, however, was temporary and the rate of drop soon increased so that the checks lost 14.3 per cent of their crop from September 16 to 22 as compared with a 17.5 per cent drop for the former period, September 9 to 15. All treatments repeated on September 15 resulted in satisfactory control of drop until the harvest was completed on September 22. Since the duplicate treatments were omitted from only four trees of each group and some of those were harvested early, it is not possible to conclude that the initial applications made September 8 showed any increasd effect in drop control after the rains. Although, it seems that this may have been the case where the strongest concentration of 30 ppm was used. The data do indicate rather clearly that an inadequate supply of soil moisture may seriously reduce the effects of naphthalene acetic acid in delaying the preharvest drop.

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A Comparison of Winter and Early Spring Applications of Nitrogen to Tung Trees

By Arnaud J. Loustalot and Felix S. Lagasse, *U. S. Department of Agriculture, Gainesville, Fla.*

Applications of mineral fertilizers to tung trees in Florida are generally made sometime during the month of March or later, by which time the trees have usually started growth and set fruit. Because rainfall is comparatively light at that season of the year in tung-growing areas of that state, considerable time may elapse before the minerals applied are dissolved, absorbed, and transported to the growing points. Under these conditions, sufficient inorganic nutrients for optimum growth may not be available to the tree at the time they are needed for active early growth, with the result that the terminal growth, the size and number of leaves, and ultimate fruit production may be somewhat reduced. This situation would be more pronounced in orchards below average vigor, or where the trees have received little or no previous fertilization. From the standpoint of orchard and farm management, the March fertilizer applications are made at a season when the demands for labor for other farming operations are usually heavy.

Tung growers frequently ask whether a fertilizer such as ammonium nitrate applied during the winter is as effective as when applied in the spring. An experiment was set up to obtain information on this very practical question. Ammonium nitrate was used because it is easily traced in the plant tissues and because Sitton and Loustalot (3) have shown that a liberal supply of nitrogen is necessary for good yields. The specific objectives were: (1) To determine the effect of time of application of nitrogen on its absorption and translocation to the growing points of the tree and (2) To determine the relative effect of time of application of nitrogen fertilizer on subsequent shoot and leaf growth. This is a preliminary report on this study covering the first year's results.

MATERIALS AND METHOD

The experiment was set up in December 1944 in a 7-year-old seedling orchard on a Norfolk fine sand soil near Brooker, Florida. The orchard had previously been well fertilized and cultivated, the trees were in good vigor, and a moderately heavy crop had been borne in 1944.

Forty-five trees, fairly uniform as to size and previous crop, were selected and divided into nine blocks or replications, each block consisting of five single-tree plots. One plot (tree) in each block was fertilized on December 22, one on January 20, one on February 19, one on March 22; and the fifth, which served as a check, remained unfertilized until June 15 when the cooperator made an application of 8 pounds per tree of .9–4.2–12.0 fertilizer carrying 4.2 per cent of MgO, 1.7 per cent of ZnO, 3.3 per cent of MnO, 1.1 per cent of CuO, and .9 per cent of FeO. The experimental fertilizer application consisted of 4½ pounds of ammonium nitrate, applied beneath the spread of the branches of each tree.

On December 22, before any fertilizer had been applied, three samples of roots were collected, one composited from the trees of blocks I to III, another from blocks IV to VI and the third from blocks VII to IX. The unfertilized trees were sampled in a similar manner on January 20, February 19, March 22, and April 26. Beginning on January 20 and on each sampling date thereafter composite samples were taken by the same procedure from the trees fertilized December 22. The trees fertilized on January 20 were similarly sampled beginning February 19; those fertilized February 19 were sampled beginning March 22; and those fertilized March 22 were sampled on April 26. Thus on April 26 five sets of three composite root samples each were collected.

On each date, on which root samples were taken and also on June 26, samples of twigs and buds, and/or shoots and fruits were collected in a manner identical with that described for root samples.

Root samples consisted of fibrous roots growing within the surface foot of soil and were taken from four sides of the trees. At the first three dates, ending with February 19, the trees were dormant and samples of 1-year-old twigs[1] and dormant buds were obtained. Between February 19 and March 22 the trees blossomed and set fruit. Thus on March 22 and April 26 samples of the new shoot[1] and leaf

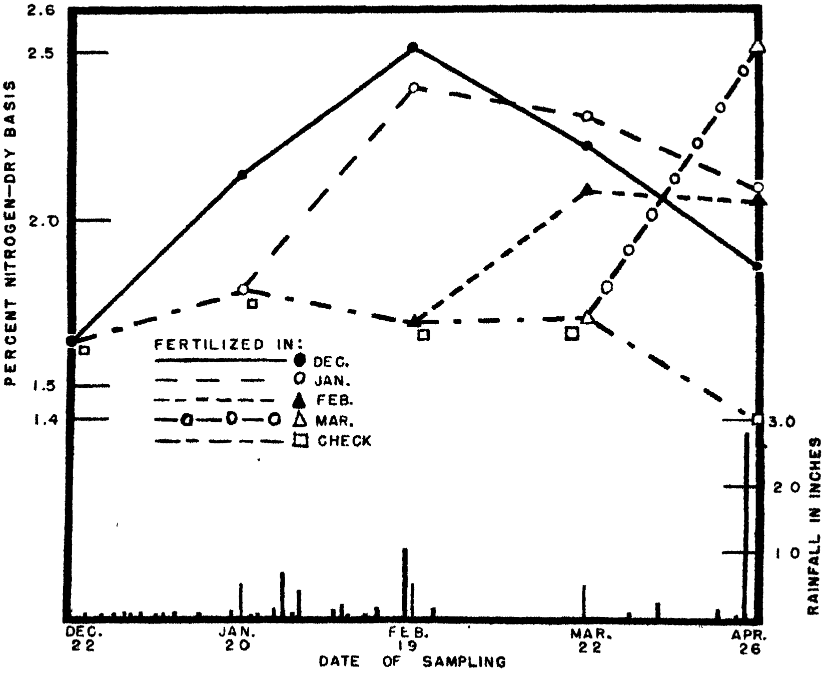

FIG. 1. Nitrogen trends in roots of tung trees fertilized at different times during winter and spring of 1944–45.

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[1] As defined by Chandler (1).

growth and young fruits were obtained instead of dormant buds. On each of the first five dates 1-year-old twigs including dormant buds or 1945 shoots were taken at random from each tree. On June 26 each composite sample consisted of 30 representative shoots, 10 from each tree, and included only the current year shoots, leaves, and fruit. Number, length, and weight of current year shoots, and number and weight of leaves per terminal growing point were determined.

The samples were dried at 70 degrees C in a Proctor and Schwartz drier and ground in a Wiley Mill for analysis. Total nitrogen was determined according to the A. O. A. C. method.

RESULTS

The nitrogen trends in the tissues of trees fertilized at different times during the winter and early spring on a percentage dry-weight basis are shown graphically in figures 1 to 4.[2] It will be seen from these data that, under the conditions of this experiment, applications of ammonium nitrate to tung trees as early as December (Fig. 1) resulted in a marked increase in percentage of nitrogen in the roots within a month after the fertilizer was applied. Subsequent samplings at monthly intervals reveal that the percentage of nitrogen in the roots of these trees increased till February 19 and then declined. Later

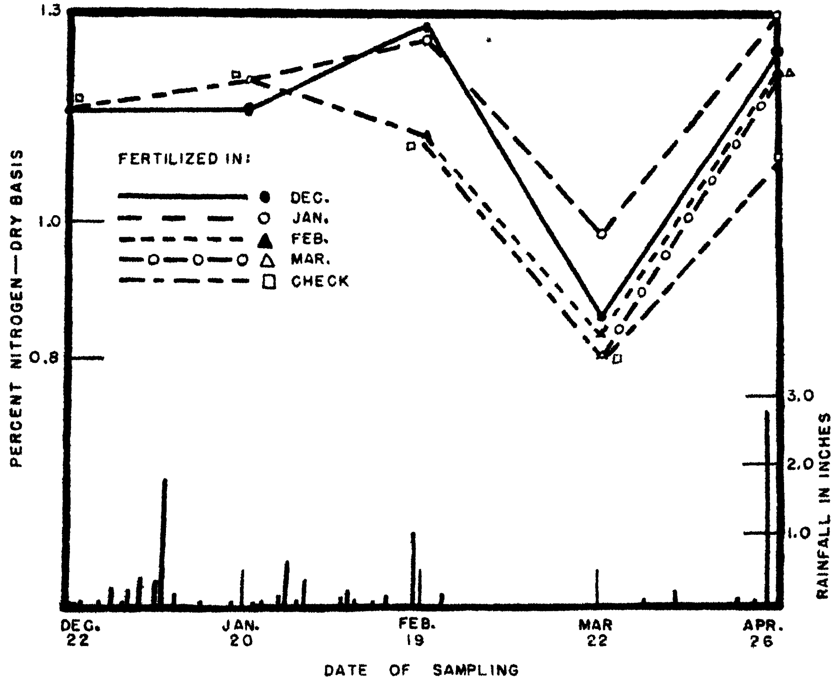

FIG. 2—Nitrogen trends in 1-year twigs of tung trees fertilized at different times during winter and spring of 1944–45.

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[2] The authors are indebted to Mr. Judson H. Lassiter for the drawing of the graphs.

samplings, March 22 and April 26, showed a marked increase of nitrogen in the new vegetative growth and fruit of the trees fertilized in December as compared with that in similar tissues of the check trees (Figs. 3 and 4). The trees fertilized in January showed similar trends except that the percentage of nitrogen in the roots of the trees fertilized in January declined to a lesser extent in April than it did in roots of trees fertilized in December. Likewise, the roots of the trees fertilized in February and March showed a marked increase in nitrogen content 1 month after fertilizer was applied, which tended to be reflected in the concentration of nitrogen in the new shoots. However, on April 26 the nitrogen in tissues, other than the roots, of trees fertilized in February and March was not so high as in trees fertilized earlier. All shoots, even those of the check trees, tended to be high in nitrogen on March 22, due to their succulent condition.

Of the several parts analyzed, the 1-year-old twigs (Fig. 2) were least affected by the nitrogen applications. Nitrogen in twigs from both fertilized and unfertilized trees remained fairly constant until March 22, at which time there was a marked decline in all trees, coinciding with the marked rise of nitrogen in the new vegetative growth (Fig. 3). However, by April 26, there was an increase in nitrogen to about the original concentration in the 1-year-old twigs of all trees and a decline in the percentage of nitrogen in the new vegetative shoots, which were becoming woody.

The analyses of the samples taken on April 26 showed considerably

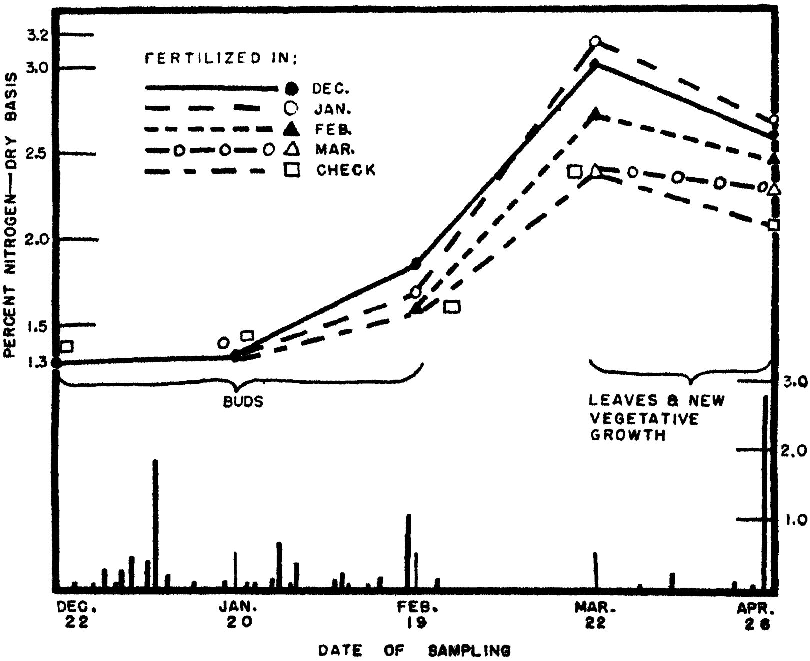

FIG. 3. Nitrogen trends in buds and new vegetative growth of tung trees fertilized at different times during winter and spring of 1944–45.

more nitrogen in the roots of trees fertilized in March than in those of trees fertilized at the three earlier dates (Fig. 1), but in the fruit (Fig. 4) and new vegetative growth (Fig. 3) the reverse was true, indicating that the nitrogen applied in March had not yet reached the growing points to the same extent that it had in trees fertilized earlier in the season. There was no indication that trees fertilized in December, January, or February blossomed any earlier than those fertilized in March.

The possibility of loss of nitrogen from leaching exists, when the application is as early as December or January. However, this does not seem to have occurred to any appreciable extent during the past season for the trees receiving nitrogen at those times were found in general to be higher in nitrogen than those receiving it later. It should be stated, however, that the spring of 1945 was somewhat drier than usual and it is possible that the differences obtained between early and late treatments another year may not be so great. On the other hand, the 20-year average rainfall is only about 3 inches per month for the period concerned, and, for this reason, the danger of loss of nitrogen from leaching when applied around January 1 in seasons of normal rainfall and in sandy soils seems slight.

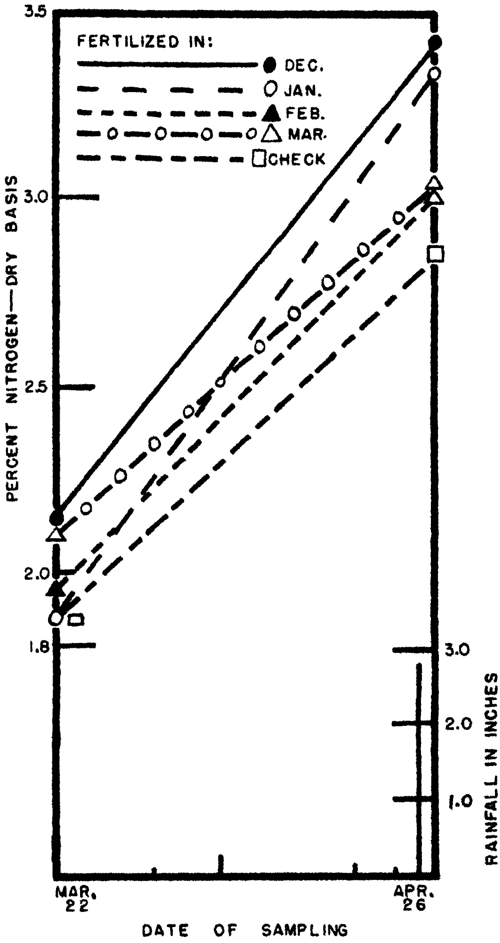

Fig. 4. Nitrogen trends in fruit from tung trees fertilized at different times during winter and spring of 1944–45.

The growth data presented in Table I show the beneficial effects of early application of ammonium nitrate on terminal shoot and leaf growth under the conditions of this experiment. By June 26 trees that had been fertilized in December and January had made longer and heavier shoot growth per terminal than had those fertilized later. The differences observed ap-

TABLE I—SHOOT AND LEAF GROWTH AS OF JUNE 26, 1945 ON TUNG TREES FERTILIZED AT DIFFERENT DATES FROM DECEMBER TO MARCH WITH 4½ POUNDS OF AMMONIUM NITRATE PER TREE

Date of Fertilizer Application	Average Number of New Shoots per 1944 Terminal	Average Total Length of Shoots per 1944 Terminal (Inches)	Average Dry Weight of Shoots per 1944 Terminal (Grams)	Average Number of Leaves per 1944 Terminal	Average Dry Weight of Leaves per 1944 Terminal (Grams)
Dec 22............	2.11	13.42	4.21	27.44	27.0
Jan 20......... .. .	2.06	11.35	3 29	23.23	23.4
Feb 19............	1.88	10.88	3.27	20.10	19.7
Mar 22.............	1.94	10.34	3.05	23.23	20.0
Check*........ . . .	1.70	9.74	2.76	20.52	18.2

*These trees, as well as all others in the study, received on about June 15 the grower's fertilizer treatment, which consisted of 8 pounds per tree of the following fertilizer:

N -- P - K MgO MnO Cu - ZnO - FeO
.9 - 4.2 - 12.0 4.2 3.3 1.1 - 1 7 - .9

proach but do not attain statistical significance at the .05 level. Kilby and Parker (3) have shown that about 90 per cent of the terminal growth of tung trees is completed by the latter part of June in southwestern Mississippi. The advantages of winter fertilization is further shown in the larger number of leaves produced on the trees fertilized in December than on those fertilized in spring.

TABLE II—NITROGEN CONTENT OF LEAVES, SHOOTS, AND FRUITS SAMPLED JUNE 26, 1945 (DRY-WEIGHT BASIS)

Date of Fertilizer Application	Shoots (Per Cent)	Leaves (Per Cent)	Fruit (Per Cent)
Dec 22.	0.89	2.57	1.50
Jan 20......	0.90	2.60	1.37
Feb 19..	0.89	2.67	1.38
Mar 22...	0 93	2.60	1.41
Check*.	0 67	2.39	1 17

*These trees, as well as all others in the study, received on about June 15 the grower's fertilizer treatment, which consisted of 8 pounds per tree of the following fertilizer:

N -- P - K MgO MnO Cu - ZnO - FeO
.9 - 4 2 - 12.0 4 2 3.3 1 1 - 1.7 - .9

The data presented in Table II show that for all practical purposes there was no appreciable difference on June 26 between the percentage nitrogen content of leaves and shoots from trees fertilized in winter and those fertilized in March. The fruits from trees fertilized in December had on the average a somewhat higher content of nitrogen than fruit from trees fertilized later but the differences are not statistically significant. The data also show that the nitrogen content of shoots, leaves, and fruit from the check trees, which received only .08 pound actual nitrogen per tree, is somewhat lower than that of similar tissues of the trees fertilized with ammonium nitrate plus mixed fertilizer, comprising a total of 1.52 pounds actual nitrogen per tree.

DISCUSSION

It would appear from the data at hand that ammonium nitrate applied to tung orchards as early as December or January is absorbed by the roots and translocated to the growing points of the trees fully as well as and perhaps better than when applied in March, since the nitrogen was found in greater concentration in the shoots at the time growth started in the spring. The trees receiving the early fertilizer application also made the most growth to June 26. These data suggest that the trees are capable of utilizing this nitrogen present in the tissues at the time growth starts, thus accounting for the good growth early in the season. The fact that larger leaves and shoots are formed early in the season enables the tree to manufacture a greater quantity of organic nutrients which are necessary for oil synthesis and high yields.

In the locality in which this experiment was carried out there is usually a drought in the spring, and in the spring of 1945 it was more acute than usual. Thus, if a grower had applied ammonium nitrate fertilizer in March, the maximum benefits would not have been realized until late April or early May, several weeks after growth started. Ammonium nitrate or other nitrogenous fertilizer materials applied during the winter months are more likely to be taken up in time for optimum spring growth because they will be in contact with the roots for a longer period of time before top growth begins. Since the soil on which this test was made is sandy, the tendency to leach is greater than it would be on a heavier soil having a higher base-exchange capacity. The data obtained in this experiment show that the roots actively absorbed nitrogen, even in mid-winter. Immediate absorption would minimize loss from leaching, which suggests that even on sandy soils in this area such losses would not be excessive in comparison with losses from late applications.

SUMMARY

The data obtained show clearly that, under the conditions of this experiment, ammonium nitrate applied as early as December and January was absorbed by the roots and transported to the growing points previous to the time growth started in the spring. The new vegetative growth and fruit of trees fertilized in February and March contained less nitrogen on April 26 than did that of trees fertilized in December and January.

The 1-year-old twigs were least affected by the nitrogen applications. The nitrogen in the twigs from both treated and check trees remained fairly constant until March 22, at which time there was a marked decline in all instances, which coincided with a sharp rise in nitrogen content in the new vegetative growth. By April 26, the nitrogen in the twigs had returned to its original level, while that in the new shoot growth showed a decline.

Trees fertilized early in winter made better growth by June 26, as indicated by shoot weight and length and by number and weight of leaves, than trees fertilized later, some of the differences closely approaching statistical significance at the .05 level. By June 26 the concentration of nitrogen in leaves, shoots, and fruit of trees fertilized early and those fertilized late were not appreciably different, with the exception of fruit from trees treated in December, in which the percentage of nitrogen was somewhat but not significantly higher.

From the data obtained, winter fertilization of tung orchards with ammonium nitrate seems more practical than spring fertilization, since the trees readily absorbed the nitrogen and translocated it to the growing points. Consequently, it was available when spring growth started. In addition, the fertilizer materials can be applied at a time when the demand for labor, at least in some tung areas, is not so heavy as it is in the spring.

There was no evidence that early fertilization caused the trees to bloom earlier than unfertilized trees.

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Notes on Apple Set and Growth, 1945[1]

By R. H. ROBERTS, *University of Wisconsin, Madison, Wisconsin*

SEVERAL observations were made in 1945 on various influences affecting the setting and development of apples. The relation of the stage of blossom development to ovule injury from freezing already has been recorded (2). Other notes were upon pollination, dropping, especially the "June drop", apple shape (length), and apple size increase at harvest time.

Most of the pollination tests were lost or made questionable by frost injury. In one orchard, dependable results were secured with Golden Delicious. Counts made after the blossom drop showed the following percentage sets (spurs thinned to two blossoms each and the petals removed before pollinating): Wealthy pollen, 66.7; Northwestern Greening, 57.2; McIntosh, 48.6. This average of 57.5 dropped to 13.4 when emasculating was done by removing the sepals. Earlier collected pollen of Cortland, Jonathan and Starking gave percentage sets of 10.3, 28.5 and 27.3 respectively, using blossoms with only the petals removed. Unpollinated blossoms with petals removed set no fruits.

Observations were again made on the relation of blossom structure to the way bees extract nectar from them. In 1944 (1) it was noted that honeybees collected nectar from Delicious blossoms in 80 per cent of their visits without touching the stigmas. This season the percentage dropped to approximately 50 as the petals were smaller and more cupped, the result being that bees entered the blossom more often from the top.

"Pollination weather" was generally poor in Wisconsin in 1945. This fact and the low bee population in some orchards resulted in as few as 58 Wealthy fruits for each 100 blossoming spurs at the time of the first drop, just after blossoming. Under favorable conditions, it was as high as 402.0. Average counts follow: Delicious, 44.0; Golden Delicious, 321.0; McIntosh, 78.6; Wealthy, 228.5. From previous experiences, it is commercially desirable to have about 75 to 100 fruits for each 100 blossoming spurs at this time. More than this contributes to biennial bearing without increasing the crop.

Poor pollination and set conditions are further shown by the relatively small numbers of developing ovules in the second wave of dropping fruits (of about 1/4 to 5/8 inch in diameter). Counts made in five orchards give the following averages: Delicious, 5.7; Duchess 2.0; Golden Delicious, 8.8; McIntosh, 4.6; Wealthy 3.5. In orchards having considerable defoliation from scab at this period, there seemed to be a "sympathetic" dropping of fruits accompanying the leaf drop, with the result that orchards which were badly infested with scab had a small to almost no crop.

The numbers of developing seeds in June-drop fruits also reflect poor pollination conditions. The average seed number in drop fruits of Wealthy from 11 orchards was 4.1 (range: 0.9 to 8.1). The number for McIntosh from nine orchards was 5.0 (range: 2.8 to 6.9). The orchard of Wealthy that averaged .9 seeds for each drop fruit (80 per cent seedless) was very heavily fertilized with nitrogen. The number of seeds in fruits at harvest time in this orchard was 2.7; 18.4 per cent of these had no fully developed seeds.

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[1] Published with the permission of the Director of the Agricultural Experiment Station.

It was quite apparent that a heavy June drop of McIntosh, which is unusual for this variety, was induced in a number of orchards by the use of too much ammonium nitrate. Trees with "blue-green" foliage in July had a heavy drop, while those with a "yellow-green" foliage had a light drop. The following figures were secured in the University orchard where dense trees (unpruned or lightly pruned) with cultivation had a too green color in comparison to light green trees under sod culture and with open pruning. The data are numbers of drop apples on the ground for each 100 on the tree above the area counted; yellow-green, 13.0; green, 32.5; blue-green, 116.1. The tree populations were secured by counting the number seen through a hollow 6-inch square held at arm's length.

It was noted that the "seedless" Wealthy mentioned above tended to be flat in shape, Fig. 1. Measurements and seed counts of Wealthy and McIntosh showed a relation between number of seeds and length of fruits for these varieties (Table I).

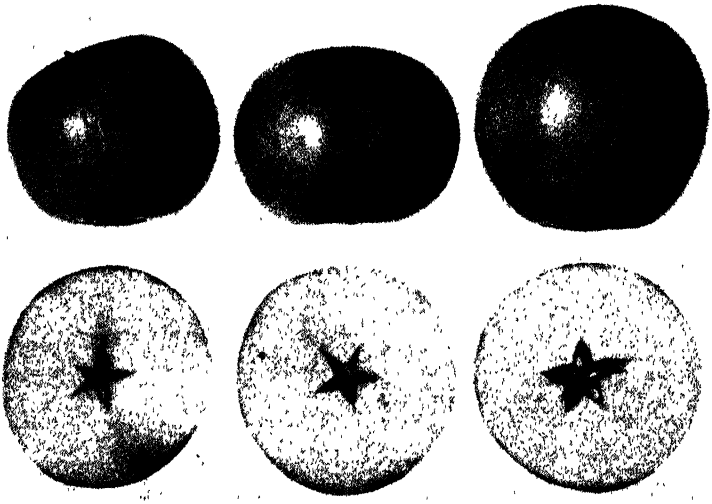

FIG. 1. Relation of Wealthy shape and seed number, 1945. See Table I.

The growth rate of several varieties as harvest time approached was secured by averaging the width (greatest diameter) of 20 specimens of each. All continued to enlarge until they dropped (Wealthy and McIntosh) or were picked (other varieties).

TABLE I—LENGTH, WEIGHT AND SEED NUMBERS OF WEALTHY AND McINTOSH APPLES, 1945

Shape	Average Number Seeds	Average Weight (Grams)	Average Weight (Grams)		Number of Seeds	
			0 4 Seeds for Each Fruit	5 and More Seeds for Each Fruit	120 Grams or Less	121 Grams or More
Wealthy....	—	—	111.8	119.2	3.3	4.1
Long . . .	6.14	151.4	—	—	—	—
Flat . .	2.27	121.4	—	—	—	—
One-sided..	2.85	103.0	—	—	—	—
McIntosh ...	—	—	120.0	141.4	3.2	5.8
Long. ...	5.97	140.1	—	—	—	—
Flat.	3.04	119.8	—	—	—	—
One-sided	2.04	119.3	—	—	—	—

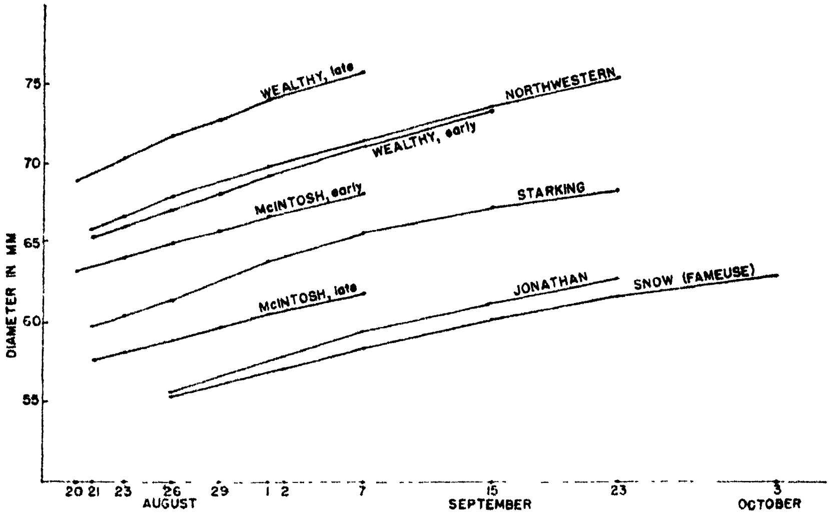

FIG. 2. Growth rate of several varieties just prior to harvest. The "early" and "late" McIntosh and Wealthy were from trees having different rates of coloring and maturity.

SUMMARY

Golden Delicious set with pollen of Cortland, Jonathan, McIntosh, Northwestern Greening, Starking and Wealthy.

Delicious blossoms have a structure permitting honeybees to extract nectar without pollinating the blossoms in a large percentage of visits.

Varieties vary greatly in the initial setting of blossoms.

The numbers of developing ovules in "drop" fruits and mature seeds for each fruit at harvest time were very low in some orchards in 1945. "Seedless" fruits were very common.

Too much ammonium nitrate induced a June-drop of McIntosh. This drop was correlated with a too green color of the foliage.

Fruit shape was related to number of seeds in each fruit. Apples with few seeds were flatter.

Individual fruits continued to enlarge until the time they dropped or were harvested.

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Thinning Apples at Blossom Time with Growth Regulating Substances and Oil-Wax Emulsions[1]

(A Progress Report)

By T. C. STEBBINS, A. L. NEAL and V. R. GARDNER, *Michigan State College, East Lansing, Mich.*

AN INEXPENSIVE and thoroughly dependable method of thinning apples, sufficiently early in the season to improve size of fruit and to induce annual bearing is still an important problem. The employment of materials for this purpose, which are not caustic and not damaging to the foliage is of special interest. Results obtained in 1944 with certain oil-wax emulsions developed by the Department of Agricultural Chemistry at Michigan State College, suggested their value as blossom thinning agents (2, 3). The hope that such materials would reduce fruit set, not by killing the blossoms as do other materials tried in previous years, but simply by coating over the stigmatic surfaces and thus preventing either pollination or pollen germination. Three types of oil-wax emulsions have seemed most promising, namely: No. 82, No. 222 and T.S.S. App-L-Set, a trade name for the sodium salt of naphthyl acetic acid, manufactured by the Dow Chemical Company, has given promising results for several seasons with no apparent harmful effects (1); and DN Dry-Mix No. 2, a dinitro compound in powder form has also proved effective, although it may produce injury to the foliage.

The data presented in this paper deals with the three types of materials mentioned above applied as blossom sprays in various concentrations and combinations to trees of Wealthy, McIntosh and Duchess apples in "Northern Orchards" at Cheboygan, Michigan, during the spring of 1945.

TREATMENTS

In a mixed block of Wealthy, Snow and Northern Spy varieties (two rows of each rotated across the block) six to seven Wealthy trees at early full bloom stage were sprayed with each material. Examination of numerous blossoming spurs revealed that a majority of the center blossoms and an occasional side blossom had been pollinated. This stage of bloom was chosen on the theory that if the oil-wax emulsions were effective in preventing pollination by coating the stigmas, some pollination must be permitted before the material is applied. In order to determine the time interval over which these materials might be applied commercially and still effect thinning, the treatments were duplicated 2 days later on the same number of trees in another section of the same

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rows when the majority of the blossoms were at the late full bloom or early petal fall stage. At the time of spraying only a few blossoms were still unopened.

The blossoming spurs on each of four trees in each treatment were counted on two tagged branches of approximately similar size and location. One of these branches was covered with a large paper bag just prior to spraying while the other branch was left uncovered and, therefore, received the same spray treatment as the entire tree. Thus it was possible to have both the sprayed limb and the unsprayed check limb on the same tree. The trees were given a thorough application of the spray material. For trees 12 to 14 feet in height, a minimum of approximately 15 gallons of material were required per tree. As soon as the foliage was dry the paper bags were removed.

McIntosh and Duchess were treated only at petal fall and calyx stages, respectively, in the manner described above with the materials given in the accompanying table. Treatment of these two varieties, being more or less incidental to the treatment on Wealthy, was made at the stage of bloom in which they were found upon arrival at the orchard. A heavy bloom was present on all varieties and beehives were distributed throughout all blocks to favor pollination.

Following the summer drop a count was made of the number of apples borne on the tagged sprayed and control branches. Calculations were made of the number of apples per hundred blossoming spurs and of the percentage total set thinned off.

Results and Discussion

The spray materials used and the results obtained are shown in Table I.

DN Dry-Mix No. 2 at concentrations of ½ and 1 pound per 100 gallons burned the blossom petals on Wealthy within 24 hours after application. The foliage began to curl after about 40 hours, and within a few more hours marginal burning was evident. After treatment with ½ pound of the DN per 100 gallons the same effect was noted somewhat sooner on McIntosh while only leaf curling without actual burning was observed on Duchess.

The application of 1 pound of DN Dry-Mix No. 2 per 100 gallons at full bloom and also at early petal fall reduced the set of Wealthy 74.3 and 65.6 per cent respectively. The use of ½ pound per 100 gallons at full bloom reduced the set 73.0 per cent as compared with 23.8 per cent when applied at petal fall. McIntosh at petal fall and Duchess at calyx stage were thinned 99.3 and 40 per cent respectively by applying ½ pound of this material per 100 gallons of spray.

App-L-Set in all concentrations, with or without the oil-wax emulsion, dwarfed and curled the spur leaves of all three varieties but caused no actual burning. Measurements made late in the season showed the average area of the Wealthy spur leaves sprayed with 20 ppm (½ pound per 100 gallons) to have only slightly over half the area of unsprayed leaves.

App-L-Set at 20 ppm thinned Wealthy at both stages as much as, or more than did DN Dry-Mix No. 2 at a level of 1 pound per 100

TABLE I—COMPARATIVE EFFECTS OF VARIOUS BLOSSOM THINNING SPRAYS ON WEALTHY, MCINTOSH AND DUCHESS APPLE TREES

Material Used	Amount per 100 Gallon Spray	Wealthy						McIntosh			Duchess		
		Full Bloom			Early Petal Fall			Petal Fall			Calyx		
		Apples Per 100 Spurs		Per Cent Thinned	Apples Per 100 Spurs		Per Cent Thinned	Apples Per 100 Spurs		Per Cent Thinned	Apples Per 100 Spurs		Per Cent Thinned
		Check	Sprayed		Check	Sprayed		Check	Sprayed		Check	Sprayed	
DN Dry Mix No. 2.....	1 pound	17.5	4.5	74.3	22.7	8.0	65.6	—	—	—	—	—	—
DN Dry Mix No. 2	½ pound	24.2	6.5	73.0	22.7	17.3	23.8	44.4	0.3	99.3	26.0	15.6	40.0
App-L-Set (20 ppm)....	½ pound	25.6	5.8	77.4	33.7	7.0	79.2	38.0	4.0	89.5	19.4	12.7	34.5
App-L-Set (15 ppm). ..	6 ounces	33.5	11.0	67.0	40.2	20.0	50.3	36.4	1.4	96.1	19.4	14.9	23.0
App-L-Set (10 ppm). ..	¼ pound	19.5	8.9	54.0	26.0	15.6	40.0	40.5	10.9	73.0	24.4	18.0	26.3
App-L-Set (10 ppm) + Oil Wax No. 222	¼ pound 1 quart	31.8	16.6	48.0	33.3	18.3	45.0	44.6	2.5	94.3	30.1	17.5	42.0
Oil Wax No. 82	1 gallon	18.1	16.1	11.1	28.9	27.3	5.5	30.9	35.0	-16.3*	21.1	19.5	7.6
Oil wax T.S.S. .	1 gallon	16.9	17.4	- 3.0*	26.4	29.0	-9.9*	27.4	29.1	- 6.2*	—	—	—
Oil wax No. 222	1 gallon	17.4	20.1	-15.5*	25.2	25.1	0.0	30.0	35.8	-19.3*	24.9	21.0	15.7

*Set greatei on sprayed than unsprayed trees.

gallons; McIntosh at petal fall and Duchess at calyx stage somewhat less than the DN at ½ pound per 100 gallons. Lower concentrations of App-L-Set on Wealthy at both stages effected less thinning, approximately in line with the concentration used. This was not consistent in the case of McIntosh or Duchess.

The oil-wax emulsions at a dilution of $^1/_{100}$ caused no injury to the blossoms or foliage and failed to thin the fruit sufficiently to warrant their use for this purpose. When No. 82 was used on Wealthy at full bloom, only 11.1 per cent thinning resulted. When this same treatment was given McIntosh at petal fall the set was increased by 16.3 per cent while there was very little effect on Duchess when sprayed at the calyx stage. Oil-wax emulsion No. 222 increased the set of Wealthy at full bloom and McIntosh at petal fall 15.5 and 19.3 per cent respectively and thinned Duchess at calyx to the extent of only 15.7 per cent. When used on Wealthy at early petal fall, emulsion No. 82 resulted in very light thinning; while No. 222 resulted in no apparent thinning at the same stage. Emulsion T.S.S. was considered unsatisfactory not only from the standpoint of ineffective thinning, but also due to its incompatability with hard water which results in a breaking of the emulsion.

When App-L-Set at 10 ppm was used in combination with oil-wax emulsion No. 222 at a dilution of $^1/_{400}$, thinning was accomplished to the extent of 48 per cent on Wealthy at full bloom and 45 per cent at petal fall. Comparable results were obtained with Duchess at calyx stage and severe thinning to the extent of 94.3 per cent occurred when McIntosh at petal fall were treated with this same spray. When the oil-wax emulsion was used with the App-L-Set there appeared to be less dwarfing of the leaves than when the App-L-Set was used alone.

The harvest data for Wealthy showed the percentage of apples 2½ inches or more in diameter to be quite large where the trees were drastically thinned. This increase in size was, however, off-set by the decrease in yield to such an extent that the monetary returns from these trees were less than from the control trees. Moderate thinning as was accomplished by the use of App-L-Set (10 ppm) or App-L-Set (10 ppm) plus No. 222 ($^1/_{400}$) resulted in a decrease in the total yield by weight from the trees but the larger size of the fruit more than made up in monetary return for this decrease. An average of 50 per cent by weight of the apples from trees treated with App-L-Set (10 ppm) were larger than 2½ inches in diameter. This value amounted to approximately 30 per cent when the oil-wax emulsion was incorporated with App-L-Set.

This experiment is being followed through the 1946 season in order to determine if the above treatments have affected the following season's set or yield.

CONCLUSIONS

App-L-Set is an effective in-bloom thinning agent for apples. Moderate thinning was obtained on Wealthy trees with this material at a concentration of 10 ppm both alone and in combination with oil-wax emulsion No. 222 at a dilution of $^1/_{400}$. The latter combination appeared to reduce the curling and dwarfing effect of App-L-Set on the foliage. When used at a concentration of 20 ppm, thinning of Wealthy and McIntosh was too severe, whereas, at 15 ppm thinning was fairly high on Wealthy and too severe on McIntosh. McIntosh was over-thinned even at a concentration of 10 ppm.

DN Dry-Mix No. 2 at concentrations of ½ and 1 pound per 100 gallons of spray was an effective thinning agent but burned the foliage. These concentrations caused too severe thinning of Wealthy at full bloom and of McIntosh at petal fall, although the effect was lessened when the material was applied to Wealthy at petal fall or to Duchess at calyx stage.

The oil-wax emulsions used alone at a concentration of 1 gallon per 100 gallons of spray did not result in sufficient thinning.

Varieties differ greatly in the ease with which they are thinned. McIntosh was excessively thinned even at petal fall by materials which caused satisfactory thinning on Wealthy throughout the bloom period.

From this one year's trials it appears that App-L-Set (10 ppm) plus oil-wax emulsion No. 222 ($^1/_{400}$) may be used successfully for moderate thinning of Wealthy apple trees.

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Observations on the Abnormal Preharvest Dropping of Elberta Peaches during the Summer of 1945

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DURING the summer of 1945 an abnormal preharvest drop of Elberta peaches occurred in southern Indiana, southern Illinois and northern Kentucky. In Indiana this drop began in the extreme southern part of the state about June 12 and reached the Knox County section, about 50 miles north, approximately 1 week later, following the same course in southern Illinois. The peaches that were destined to drop began to shrivel on the tree, falling several days later. Examined internally the seed coats were dark and usually the jelly-like nucellus as well. Cotyledon development in dropped fruit appeared to be normal for the season in some instances. In other cases the tiny cotyledons could not be found.

This abnormal dropping began after the normal drop waves were considered to be over. Hand thinning of remaining fruits had been completed in most orchards. Late drops of similar nature in 1910 and 1927 in southern Illinois are recorded by Dorsey and McMunn (1).

In 1945 peach trees in the Knox County, Indiana area were in bloom on March 27, at least 2 weeks earlier than usual and the fruit was larger than normal for the season when the dropping referred to began. Elberta peaches on well thinned trees averaged about 1¼ inches in diameter at this time, and the pits were beginning to harden.

The rainfall during March, April, May and June was abnormally heavy and distributed so that there was little opportunity for the soil to dry out. In Knox County, Indiana, rain fell on 13 days during April, 16 days during May and on 15 out of the first 20 days of June. Official weather records show that very similar conditions prevailed in the other peach sections of Indiana and in southern Illinois. Under such conditions abnormalities of growth might be expected and the excessive rainfall received direct credit for the late dropping of peaches by many growers.

Unfortunately, the diagnosis was not so simple as there was considerable difference between orchards. Elberta and Gage appeared to be the only varieties that were susceptible. In several orchards Halehaven and Golden Jubilee, growing in alternate blocks with Elberta, were unaffected but Elberta dropped badly. The drop was more severe in some cases in orchards on well drained sandy loam soils than in orchards on heavy clays, where waterloging of the soil would be expected to cause serious complications.

In the Dixie Orchards in Knox County on sandy loam soil, a large block of vigorous 8-year-old Elberta trees which had set heavily and had no blossoms removed, were thinned to an estimated 1200 fruits per tree after the normal drop was considered to be completed. The late drop began in this orchard about June 18 and continued for 7 or 8 days taking off approximately half of the 1200 peaches that had been left on the trees. Golden Jubilee, Halehaven and other early varieties lost no fruit following thinning, nor did Shipper's Late Red (Stark strain), which follows Elberta in ripening. The drop on Gage began 7 to 10 days later than Elberta. This orchard had received an application of 400 pounds per acre of 10–6–4 fertilizer broadcast between the rows in the late fall of 1944 and a light application of the same material around the trees April 20–24, 1945. At this time the rye cover crop was heading out as it had been impossible to disc it down because of the wet weather. The discing was not done until early May. Some sections of the orchard showed indications of a possible lack of nitrogen on April 24. An application of 3 to 4 pounds of nitrate of soda was made the first week of June. Trees in this orchard had lost few leaves from arsenic injury and the general appearance of the foliage was good.

In another large commercial orchard on sandy loam soil at Oaktown, Knox County, where several applications of nitrogen were made during the spring and summer, no excessive dropping occurred. Parts of this orchard had total applications equivalent to 12 pounds of sulphate of ammonia per tree, and the grower believed he had used too much nitrogen. There was practically no foliage loss from arsenical injury in this orchard.

In the Bolten orchard in Greene County, 30 miles north of the Dixie orchards, on a heavy clay soil upon which water stood frequently during the spring and summer, the abnormal drop began about June 25 and lasted until June 30. The 9-year-old Elberta trees in this orchard had not been thinned and carried a moderate crop of fruit. The drop, however, either on a percentage basis or even on the basis of the actual number of fruits per tree was not so large as in the Dixie orchard. The Bolten orchard received 2½ pounds per tree of a 33.5 per cent N fertilizer in early April. In the late April the foliage color was rather poor. Later the ground beneath the trees was carpeted with leaves that fell as a result of arsenic injury.

In the Holden orchard in Lawrence County, some 65 miles East and a few miles North of the first orchard described, no late drop occurred. This orchard is on a heavy red clay soil underlain with limestone and would be expected to suffer from excessive moisture. The trees were carrying a moderate to light crop of fruit and had received a single light application of nitrogen early in the spring. There had been practically no loss of leaves from arsenic injury and the foliage color was very good.

No abnormal dropping occurred in a group of small peach orchards on clay soils in the east central part of Indiana where rainfall was very similar to that in the southern part of the state. In this area there was a heavy leaf drop in orchards that had received the zinc sulphate and lead schedule for curculio. Most of these orchards had received only one application of nitrogen in the early spring, but the soil is much more fertile in this area than in the southern part of the state.

In the Kentucky Cardinal orchards at Henderson, Kentucky an abnormal preharvest dropping had occurred on Elberta peaches in 1944 following one application of 4 pounds of ammonium nitrate per tree in full bloom (March 26). The total drop was such that an optimum crop was matured without thinning. On Elberta trees blossom thinned in the spring about the same amount of dropping occurred. As a result these blossom thinned trees carried 30 to 40 per cent less fruit than unthinned trees at harvest time. In 1945 full bloom was on March 25. Two pounds of ammonium nitrate per tree was applied on April 5 and 1 pound on April 26, May 31 and June 11. Both seasons 100 pounds of ammonium nitrate per acre had been applied the previous fall at the time of seeding the cover crop. No abnormal preharvest dropping was experienced in 1945. In 1944 the rainfall from March to June inclusive totalled 14.76 inches and in 1945, 28.73 inches. Halehaven set heavily both years, requiring heavy thinning and no abnormal dropping took place either season.

Another large commercial orchard of similar age and performance near the Cardinal Orchards at Henderson, received a single full bloom application of 4 to 6 pounds of ammonium nitrate per tree both years. In 1944, with a heavy set and no thinning, the drop was just sufficient to leave a fine crop that required no further thinning. In 1945, however, a heavy abnormal drop followed the customary June drop, the fruit continuing to fall for several weeks and resulting in only about half a crop of fruit.

These are typical examples of the variations involved which make it difficult to correlate the late dropping with any particular set of conditions. Direct or indirect effects of the excessive rainfall in limiting or restricting the oxygen or food supply to the roots must receive primary considerations. Direct effects of waterlogging are partially eliminated by the fact that the drop was serious in some orchards on well drained, sandy soils and practically absent on heavy soils which were literally covered with water for extended periods.

There is considerable evidence that the dropping was most severe in orchards where the nitrogen supply appeared to be low. It is unlikely that sandy soils of the types prevailing in the Dixie and the Oaktown orchards would remain long in a saturated condition. Excessive leaching of nitrates, however, would be very possible under these conditions. In orchards on heavy soils where waterlogging undoubtedly existed, possibly resulting in poor conditions for nitrate formation and utilization, observations indicate that several applications of nitrogen may have been a factor in preventing the excessive drop. Unfortunately, no good set-up for observing this point under controlled conditions presented itself, consequently, it is little more than speculation.

A point of practical importance to the commercial peach grower that seems worthy of emphasis on the basis of these observations is that Elberta is the variety most likely to suffer. During 1945, in orchards where this dropping occurred, the growers would have been better off had they delayed thinning Elberta until late June, or at least until the thinning of all other varieties was completed. The size of the crop the Elberta trees carried did not appear to be a factor correlated with the abnormal dropping. Similarly, in the case of other varieties, no dropping occurred in the orchards observed on either heavily or lightly set trees. The amount of thinning of either Elberta or other varieties, likewise, did not appear to be a factor.

While there are some apparent exceptions and insufficient evidence is available to permit definite conclusions, it appears that lack of available nitrogen during the second period of growth of peach fruits, when the pit is beginning to harden and development of the cotyledons is taking place, is a factor connected with this abnormal preharvest drop. Dorsey and McMunn (1) point out that this second period of growth differs in length among varieties, being short for some early ripening varieties and completely absent in others. They state that for Elberta this second growth period normally extends from about the 45th to the 70th day after full bloom. This covers the period during which the abnormal dropping took place in 1945.

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Effect of Climate on Fruit Form in the Kaki Persimmon

By R. W. HODGSON and C. A. SCHROEDER, *University of California, Los Angeles, Calif.*

DURING the decade 1870 to 1880 introductions of the kaki or Oriental persimmon, *Diospyros kaki,* including the Hachiya variety, were made into California both direct from Japan and from importations made by the United States Department of Agriculture (1). These led to the development of two principal centers of production based on this variety—one in the Sacramento Valley of northern California (Placer County), the other in the coastal plain of southern California (Santa Barbara, Los Angeles and Orange counties). Within a few years it became evident that the form of the fruit differed considerably in the two localities in question, being shorter and broader in the southern areas and longer and slenderer in the northern districts. To explain these differences two hypotheses were early developed: (a) that a mixture of two very similar varieties had occurred one of which had been propagated mainly in the north and the other in the south ((2), see Fig. 2 p. 16); (b) that the differences were caused by the pronounced contrasts in climatic conditions between the two areas. An opportunity to test these hypotheses was provided by the establishment in 1930 of an extensive variety collection at the Citrus Experiment Station, Riverside, where the climate is markedly similar to that in Placer County, and its replication in part a few years later on the Los Angeles campus, where the climate is typical of the southern California coastal plain.

MATERIALS AND METHODS

The materials employed in this study consisted, for the most part, of random samples of fruits from comparable trees in the two collections. In all cases the fruits compared were from trees of the same clone and on the same rootstock. The only differences had to do with the age of tree—those at Los Angeles being several years younger—the climate, and the opportunity for pollination. Since the fruits were prevailingly seedless, the latter is not considered to have been a factor of importance. Two sources of Hachiya were included in the collections—one from northern California, the other from Orange County—and also a variety introduced by the United States Department of Agriculture from Japan under the name Fugi, which is remarkably similar to Hachiya.

The climate at Riverside is characterized by a long, hot and dry growing season, with high daily maximum temperatures, while that at Los Angeles is featured by mild summer temperatures and moderate atmospheric humidity. The period of fruit maturity is several weeks earlier at Riverside and the fruit attains a higher sugar content.

Fruit measurements were made on samples of 50 to 100 fruits of the 1944 and 1945 crops of 14 varieties, including Hachiya and Fugi. By means of a specially constructed fruit caliper, length and average diameter measurements were recorded to the nearest millimeter. Since many varieties are roughly quadrangular in cross-section, it was necessary to average the two short diameters with the two diagonal diameters. The length-diameter ratio for each fruit was calculated and the mean and standard deviations of the ratios were also determined.

RESULTS

As soon as the trees came into bearing, in both plantings it became evident that the two Hachiya selections—one from northern California, the other from southern California—were identical and that Fugi comprised a separate, though very similar, variety. And, as soon as fruits of the same varieties became available from both collections, it became clear that there were differences in form in some varieties, including both Hachiya and Fugi, but not in others.

TABLE I—LENGTH-DIAMETER RATIOS OF PERSIMMON FRUITS FROM TWO DIFFERENT CLIMATIC ZONES IN SOUTHERN CALIFORNIA

Variety	Riverside L/D Ratio	Los Angeles L/D Ratio
Fugi	1 167±.041	1 070±.044
Hachiya	1.150±.043	1,063±.042
PI 59343	1.080±.042	906±.038
Hyakume	.966±.039	.780±.036
Tribble	.743±.019	704± 028
Honan Red	819±.045	.819±.044

Typical data in summary form are given in Table I from which it will be noted that five of the six varieties reported, including both Hachiya and Fugi, exhibited a larger length-diameter ratio at Riverside than at Los Angeles. These differences vary from season to season but have remained consistent as between the two localities. They are typical of the situation with a number of other varieties not reported here. On the other hand, it will be observed that Honan Red exhibited no differences as between the two climatic zones, in which respect it is also typical of a number of other varieties.

DISCUSSION

The question arises as to what is the reason for this difference in response with respect to effect of climate on fruit form as reflected by length-diameter ratio. From our data the answer is not evident. There may be significance, however, in the fact that the varieties we have found to be affected are all pointed or rounded at the apex, whereas those not affected are all flattened or even depressed at the apex.

Others factors have been reported as affecting fruit form in the kaki persimmon. Hume (3) found that the presence of seed altered the shape of some varieties from short-conical to oblate or flattened as compared with the seedless fruit. Our observations correspond to his for a fair number of varieties. On the other hand, we have noted a few varieties, Hyakume in particular, where the presence of seed seems definitely to be associated with larger length-diameter ratio, the difference between seedy and seedless fruit being considerable. Typical data bearing on this observation are shown in Table II.

TABLE II—EFFECT OF SEEDINESS ON FRUIT FORM IN THE HYAKUME VARIETY, LOS ANGELES

Number of Seed	L/D Ratio
0	.813±.036
1	.845±.038
2	.865±.045
3	.859±.050
4	.874±.066
5	.873±.020

Noguchi (4), studying metaxenia in this fruit, has reported that pollen from pointed varieties caused round-fruited varieties to become somewhat more pointed. As previously indicated, however, it is very doubtful that these factors could have been operative in our materials because of the prevailing seedlessness of the fruit.

Effects similar to those recorded here have been observed by us on other fruits and have been reported by other workers. In the Fuerte avocado and certain other varieties and with many citrus fruit varieties, it has long been recognized that the length-diameter ratio is significantly greater in the warmer inland regions than it is in coastal or near-coastal districts. Tufts (5) has reported a similar relation in the Bartlett pear. Condit (6, 7) calls attention to marked effects of climate on fruit form in the fig which, however, for the most part differ considerably from those reported here.

CONCLUSIONS

In certain kaki persimmon varieties, notably Hachiya, fruit form is markedly affected by climate. In hot, dry climates the length-diameter ratio is greater than in cooler and damper climates. The varieties thus affected are characterized by fruit apices which are pointed or rounded.

This effect is not observed with certain other varieties. For the most part these varieties are characterized by fruit apices which are flat or depressed.

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Pole Thinning of Canning Peaches[1]

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Thinning by the usual hand method requires more man-hours of labor per acre than any other operation performed in production of canning peaches in California orchards.

In years of average sets about 1 man-hour per tree, or 100 man-hours per acre, is the normal labor need. In such years trees average 2500 to 3500 fruits at thinning time, of which ordinarily 40 to 60 per cent are removed in the thinning operations.

In years of very heavy sets such as 1944, trees often average 4000 to 6000 fruits per tree at thinning time, and sometimes have set as many as 10,000 fruits. In such years usually 1½ to 2½ man-hours per tree, or 150 to 250 man-hours per acre are required to remove the excess fruits by the hand method.

When thinning started in early May of 1944, it soon became evident that there was not enough labor available in the peach districts to complete the thinning job in a reasonable period, (normally by about June 15). Also sizes were smaller than usual and there was great danger of general failure to meet marketable size requirements (2⅜-inch ring size or larger) by harvest unless extraordinary methods were used to speed up the thinning job. Therefore, it was suggested that growers knock off about 50 per cent of the fruit by use of light poles tipped with a short piece of rubber hose about ½-inch inside diameter and 10 to 12 inches long. Many growers followed this suggestion. Poles 4 to 6 feet long were used from ladders or wagon beds and similar poles 10 to 12 feet long were used from the ground. Most growers found the medium length better for the average worker than long poles, and easier on neck muscles. All moderately skillful workers could break up clusters with medium length poles. Peaches came off easiest in the early morning, and on hot days it was not desirable to use the poles on some varieties in the late afternoon.

Later the trees were gone over by hand to reduce the number left to a total commensurate with the normal estimated production capacity of each block and to give the final spacing of fruits.

This method of partial pole thinning and partial hand thinning resulted in savings of man-hours averaging 33⅓ to 40 per cent as compared with the complete hand job for similar trees in the same orchard. Also, and possibly more important, since only 10 to 20 minutes per tree were required for the poling, growers were able to get over the orchard quickly and relieve the trees of a part of the fruit load. This was undoubtedly an important factor in production of a satisfactory percentage of fruit of marketable size at harvest.

After the 1944 experience it was generally recognized that partial pole thinning was a good practice in years of very heavy sets, and growers in a few cases were doing the entire job with poles. This raised the question of the possibility of elimination of hand thinning of peaches and use of complete pole thinning as a standard practice. However, many growers raised objections mostly along the following lines:

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1. Generally smaller sizes might result at harvest, because:
   (a) Poling might remove the large fruits due to their greater weight while hand thinners remove smaller fruits.
   (b) Poorer spacing might cause poorer sizing.
2. More culls might result because fruits might be injured by poles and fruits injured by other means (insects, etc.) were picked off by hand thinners.
3. Yields of salable fruits might be reduced.

1945 EXPERIMENT

The trees used in the experiment were selected for uniformity, located near the center of a 9-acre block of 12 year old Gaume, a late midsummer cling variety, planted 22 by 22 feet and with a normal production history of 16 to 20 tons per acre of No. 1 delivered fruit. Eight trees (two picking sets of four trees each) were hand thinned on May 22, 10 days after extreme tips of pits began to harden, by two capable workmen of the grower's crew according to normal practice in the same manner as the balance of the block. Eight trees immediately adjoining (two picking sets on the opposite side of the orchard haul-out road row) were pole thinned by the writer in two stages: the first and main thinning on May 22 when about 80 per cent of the total fruits to be removed were knocked off, and the second and final pole thinning on July 5.

All poling was done with a limber peeled pine pole 11 feet long, ⅞ inch diameter at the base, and ⅝ inch diameter at the tip, with a piece of ½-inch spray hose, 11 inches long and overlapping the end of the pole two inches, fastened on the tip. Outsides of the trees were worked from the ground, and insides of trees from a standing position in the main crotches of the trees.

Two hundred fruits (25 per tree) were tagged in the pole thinned plot and two hundred in the hand thinned plot. Suture diameter measurements were taken of these fruits on May 23, July 5 and August 27 (immediately before harvest.)

Fruits were harvested in one picking August 28–30.

DATA AND DISCUSSION

Comparative Labor Requirements:—Time required for actual thinning operations is given in Table I.

The indicated saving of approximately 56 man-hours per acre, or 66 per cent, is probably a little more than could be expected on the average, but general observations indicate that savings of about 50 per cent may be expected.

Sizes of Fruits Thinned Off:—Samples of fruits removed were collected on May 22 immediately after the trees were thinned, from two pole thinned and two hand thinned trees. To get these samples, 25

TABLE I—COMPARISON OF TIME REQUIRED FOR POLE THINNING AND HAND THINNING OF PEACH TREES

Pole Thinned				Hand Thinned	
	May 22 (Minutes)	July 5 (Minutes)	Total (Minutes)		May 22 (Minutes)
8 trees	122	34	156	8 trees	455
Avg. per tree	15¼	4¼	19½	Avg. per tree	56⅞
Acre basis (90 trees) 29¼ man-hours				Acre basis (90 trees) 85⅓ man-hours	

fruits were taken at random from the inner portion and 25 from the outer portion of four 90 degree sectors of the ground area under the trees. Also, at the same time, composite samples of 25 fruits per tree were taken at random from under each of the pole thinned and hand thinned trees. Average sizes of fruits in these samples are given in Table II.

TABLE II—AVERAGE SUTURE DIAMETERS OF COMPARABLE SAMPLES OF FRUITS REMOVED FROM PEACH TREES ON MAY 22 BY POLE THINNING AND HAND THINNING

Pole Thinned	Average Suture Diameter Mm	Hand Thinned	Average Suture Diameter Mm
Sample 1, Tree 1P—200 fruits	33.0	Sample 1, Tree 2H—200 fruits	32.5
Sample 2, Tree 7P—200 fruits	32.1	Sample 2, Tree 7H—200 fruits	32.6
Composite sample 25 fruits per tree—200 fruits	32.6	Composite sample 25 fruits per tree—200 fruits	32.8

The samples indicate no significant differences in sizes of fruits removed. Apparently selection of small fruits for removal in hand thinning is not practical at normal thinning time and the hand and pole thinners both removed just an average distribution of sizes as they occurred on the trees.

Numbers of Fruits Matured by Trees:—Counts were made of numbers of fruits harvested from each tree as well as those which dropped just before or during harvest and were left on the ground after harvest was completed. This gave a record of the total numbers of fruits brought to maturity by each tree. These data are given in Table III.

A total of 2456, or an average of 307 per tree, of fruits below 2⅜-inch ring size were harvested from the pole thinned plot, and 1771, or an average of 221 per tree, below 2⅜-inch ring size from the hand thinned plot. These numbers are larger than desirable and indicate that too many fruits were left on the trees. Probably 1600 fruits per tree would have been about right in this orchard. (1) This illustrates the common tendency to leave too many fruits in hand thinning, and the possibly greater danger of errors of this kind in pole thinning. The figures above indicate that about 140 more fruits per tree were left on the pole thinned than on the hand thinned trees.

There were greater drop losses from the pole thinned trees, probably

TABLE III—NUMBERS OF FRUITS MATURED BY PEACH TREES IN POLE THINNED AND HAND THINNED PLOTS

Pole Thinned				Hand Thinned			
Tree	Harvested	Dropped	Total	Tree	Harvested	Dropped	Total
1P	1689	250	1939	1H	2024	120	2144
2P	1463	790	2253	2H	1836	190	2026
3P	1608	200	1808	3H	1393	130	1523
4P	1497	220	1717	4H	1569	200	1769
5P	2090	220	2310	5H	1752	130	1882
6P	1794	260	2054	6H	1983	190	2173
7P	1731	160	1891	7H	1646	100	1746
8P	1944	310	2254	8H	1743	70	1813
Total	13816	2410	16226	Total	13946	1130	15076
Average per tree	1727	301	2028	Average per tree	1743	141	1884

because more clusters of two and three fruits were left, and such fruits tend to be pushed off as they ripen. More time apparently should have been spent with the pole locating and breaking these clusters.

Sizes of Comparable Samples of Harvested Fruits:—A sample of ten fruits from each harvested box (or proportional fraction for part boxes) was measured before grading or culling. To get comparable representative samples, fruits were taken from the same position in each box, that is, touching the side board on one side. First the top row was taken, then those nearest the center of the second row if more than the top row were needed. Data are given in Table IV.

TABLE IV—AVERAGE SUTURE DIAMETERS IN MILLIMETERS OF COMPARABLE SAMPLES OF 10 FRUITS FROM EACH 40 POUND BOX HARVESTED FROM POLE THINNED AND HAND THINNED TREES

Pole Thinned			Hand Thinned		
Tree Number	No. of Fruits Measured	Average Suture Diameter (Mm)	Tree Number	No. of Fruits Measured	Average Suture Diameter (Mm)
1P	128	66	1H	149	65
2P	94	63	2H	140	65
3P	125	64	3H	110	65
4P	107	65	4H	124	66
5P	150	64	5H	120	63
6P	130	63	6H	140	64
7P	116	63	7H	120	65
8P	140	63	8H	120	64
Average of tree averages		63.9	Average of tree averages		64.6

These samples indicate that fruits on the pole thinned trees average slightly smaller sizes at harvest than fruits on the hand thinned trees.

Sizes of Tagged Fruits:—Groups of 25 fruits per tree in comparable positions in the upper half of the tree were tagged and measured on May 23 and measured again on July 5 and August 27. Some fruits and tags were lost before harvest time. Some were knocked off the pole thinned trees in the second thinning. Only fruits remaining at harvest time were used in the averages, which are given in Table V.

In these tagged samples the fruits on the pole thinned trees average slightly larger sizes than those on the hand thinned trees.

TABLE V—AVERAGE SUTURE DIAMETERS OF TAGGED SAMPLE FRUITS ON POLE THINNED AND HAND THINNED TREES, MEASURED IN MILLIMETERS ON MAY 23, JULY 5 AND AUGUST 27

Pole Thinned					Hand Thinned				
Tree	Number of Tagged Fruits at Harvest	Average Suture Diameter (Mm)			Tree	Number of Tagged Fruits at Harvest	Average Suture Diameter (Mm)		
		May 23	July 5	Aug. 27			May 23	July 5	Aug. 27
1P	22	34.3	40.5	67 1	1H	22	33.6	40.3	66.3
2P	19	32.9	38.1	62.9	2H	17	32.8	38.7	63.1
3P	14	33 1	38.5	66.7	3H	24	33.1	39.8	65.7
4P	18	33.5	40.3	67 4	4H	20	35.1	42.1	69.3
5P	19	34.8	40.8	68.4	5H	23	33 1	39.8	65.0
6P	21	33.6	40.1	67.0	6H	22	32.1	37.7	60.5
7P	13	32 2	37.6	63.5	7H	23	32.6	38.0	63.3
8P	16	32 3	38.7	65.8	8H	24	32.9	38.7	62.6
All	142	33 4	39.5	66.2	All	175	33.1	39.4	64.4

Classification of Culls:—Each undeliverable fruit (cull) which met the size requirements for No. 1 fruit (2⅜-inch ring size or larger) was examined and classified according to the defect causing it to be discarded. These data are given in Table VI.

TABLE VI—COMPARATIVE CLASSIFICATION OF CULLS OTHER THAN UNDERSIZE FRUIT BY TYPE OF DEFECT—POLE THINNED VS. HAND THINNED

	Pole Thinned									Hand Thinned								
	1	2	3	4	5	6	7	8	Total	1	2	3	4	5	6	7	8	Total
Probably Not Affected By Thinning Practice:																		
Over ripe	42	31	31	97	10	58	4	6	279	44	13	119	84	42	119	21	7	449
Harvest bruise	16	2	9	4	13	7	7	0	58	78	36	13	15	13	26	3	8	192
Rot	17	3	12	9	10	3	3	12	69	16	4	13	11	15	17	17	7	100
Worm	1	0	1	1	2	1	2	1	9	1	0	0	0	1	0	2	1	5
Total	76	36	53	111	35	69	16	19	415	139	53	145	110	71	162	43	23	746
Possibly Affected By Thinning Practice:																		
Scar	32	24	24	27	39	33	50	27	256	52	63	30	43	39	62	43	40	372
Visible split-pit	23	8	42	17	28	18	2	16	154	35	44	33	21	35	41	14	29	252
Blossom end breakdown	4	0	2	3	0	1	0	0	10	6	1	4	10	1	1	9	4	36
Double	2	1	1	6	3	2	6	1	22	2	3	1	2	1	2	0	3	14
Sunburn	4	7	4	1	5	5	0	2	28	31	10	14	8	11	11	5	10	100
Gum	0	0	0	0	1	2	0	0	3	5	1	5	2	0	1	1	3	18
Total	65	40	73	54	76	61	58	46	473	131	122	87	86	87	118	72	89	792

Pole thinning did not scar fruits. Smaller numbers of split pits and blossom-end breakdown fruits on the pole thinned plot were probably accounted for by delayed removal of part of the fruits from this plot. (2, 3) Doubles and gummy fruits were not a serious problem in this orchard. The greater numbers of sunburned fruits in the hand thinned plot suggests that hand thinners leave more exposed fruits.

Yields of Fruit Harvested:—The fruit was harvested by the grower's picking crew, and boxes stacked in separate piles from each tree for measuring size, grading, and culling. Yields given do not include fruits which dropped just before harvest or fell during the harvesting operation. No. 1 fruits were those actually delivered to the cannery, (good fruit free from blemishes, 2⅜-inch ring size or larger). Yields were recorded in tenths of boxes and average weights of boxes used to get weights of fruit per tree. Data are given in Table VII.

TABLE VII—COMPARATIVE YIELDS IN POUNDS OF FRUIT HARVESTED FROM POLE THINNED AND HAND THINNED PEACH TREES

Pole Thinned					Hand Thinned				
Tree	Culls 2⅜ Inches Ring Size and Over	Size Culls (Under 2⅜ Inches Ring Size)	No. 1 Fruit (Delivered)	Total	Tree	Culls 2⅜ Inches Ring Size and Over	Size Culls (Under 2⅜ Inches Ring Size)	No. 1 Fruit (Delivered)	Total
1P	44	40	428	512	1H	76	45	475	596
2P	12	55	309	376	2H	48	35	477	560
3P	32	50	418	500	3H	68	15	357	440
4P	44	45	339	428	4H	56	35	405	496
5P	28	85	487	600	5H	40	50	390	480
6P	40	55	425	520	6H	80	60	420	560
7P	12	70	382	464	7H	28	35	417	480
8P	12	60	488	560	8H	36	55	389	480
Total	224	460	3276	3960	Total	432	330	3330	4092

No. 1 fruit delivered from the hand thinned plot totaled 54 pounds more than that delivered from the pole thinned plot. This difference of about 7 pounds per tree is apparently insignificant.

The amount of small fruit (under 2⅜ inches) produced was larger than desirable. The slightly larger proportion of small fruits on the pole thinned trees was apparently the result of leaving about 140 more fruits per tree on the pole thinned trees than on the hand thinned trees as shown in Table III. The somewhat larger proportion of culls over 2⅜-inch diameter on the hand thinned trees approximately counterbalanced the smaller proportion of small fruits, resulting in approximately equal quantities of No. 1 delivered fruit from both plots.

Yields of No. 1 delivered fruit as shown above were at the rate of approximately 18½ tons per acre. The yield of the entire block averaged 18 tons per acre, indicating that the 16 trees were representative of the block.

CONCLUSIONS

Neither pole thinning nor hand thinning, as normally practiced, are very selective for size at the usual thinning time. A cross section of sizes of fruits on the tree is removed by either method.

Yields and sizes are dependent mainly on the number of fruits left on the trees in relation to the productive capacity of the tree, rather than on very careful spacing of fruits.

Where there are no special problems such as excessive numbers of doubles or Phillips type gumming, complete pole thinning seems practical for peaches.

By making it possible to get over the orchard faster, pole thinning will help sizing of fruits under commercial orchard conditions when sets are very heavy or thinning labor is scarce.

Savings up to about 50 per cent of man-hours required for hand thinning seem possible for adoption of the pole thinning practice.

Hose tipped poles of the kind used in this test do not scar fruits.

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Further Data on the Control of Storage Scald of Apples by Means of Carbon Dioxide[1] [2]

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PREVIOUS reports (3, 4) have shown the possibility of controlling storage scald of Rhode Island Greening apples by exposing the fruit in cold storage to 30 and 60 per cent carbon dioxide for periods of 3 to 10 days. The treatments were most effective when given directly after harvest, and no harmful effects on flavor were observed when the fruit was kept for 10 days in 60 per cent carbon dioxide. Thornton (6) found no ill effects from exposing McIntosh apples to 48 per cent carbon dioxide for 6 to 7 days at 32 degrees F and Delicious to 83 per cent for 7 days. Allen (1) kept Yellow Newtown apples in 35 per cent carbon dioxide and 5 per cent oxygen for 15 days without injury to the fruit. The atmosphere of high carbon dioxide, while not harmful to fruit, is deadly to rodents, and was found to be an excellent agent for the control of rodents in storage (5).

MATERIAL AND METHODS

The following varieties of apples were provided for the study from the College orchards: Rhode Island Greening, McIntosh, Baldwin, Northern Spy, Stark, Delicious, Jonathan, Yellow Transparent, Gravenstein, Duchess, Wealthy, and Winter Banana. The Cortland apples were grown in Connecticut.

The carbon dioxide was obtained from dry ice, a little over 122 pounds being required for 1000 cubic feet of gas. Each of the two treatment rooms contained 500 cubic feet and were kept at 32 degrees F. Since the rooms were not gas-tight, an excess of dry ice was placed in partially open 55-gallon steel drums, and the concentration of the gas controlled by opening the drum to increase diffusion of the gas, or by ventilating the room when the concentrations were too high. Concentrations were usually maintained at the desired level ± 2 per cent.

Because the rooms were small and the fruit was stacked close to the drums containing the dry ice, some of the fruits were frozen. This freezing should be guarded against when dry ice is used as the source of carbon dioxide.

Fruits were kept overnight in ordinary storage at 32 degrees F following harvest, and treatments were begun the following afternoon unless otherwise indicated. After the treatments were completed, the apples were stored in a large refrigerated room with untreated fruit for the remainder of the storage season. At the beginning of February, scald counts and pressure tests were made. The fruit was then exposed to room temperature for 4 days and the scald counts repeated. Fruits were rated as free from scald, slightly scalded, or severely scalded. The apples listed as slightly scalded had, in fact, only a trace of the disease.

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[1] Contribution No. 685. Rhode Island Agricultural Experiment Station, Kingston, R. I.

[2] The financial assistance of the Refrigeration Research Foundation in carrying on this study is gratefully acknowledged.

To secure data on probable cost of treatment, quantities of dry ice were distributed and exposed in different ways in an 8500 cubic foot room which should hold 2500 to 3000 bushels of fruit. The concentrations obtained were measured by withdrawing samples of air from various parts of the room through rubber tubing leading to gas analysis apparatus just outside of the storage room.

RESULTS

Data for the varieties, Cortland, Rhode Island Greening, McIntosh, and Baldwin are presented in Tables I to IV, and the results obtained with additional pickings of these varieties, as well as results with other varieties, are briefly summarized.

Rhode Island Greening is very susceptible to scald, and the light green skin so accentuates the brown scald areas that the sales value is seriously lowered in spite of the fact that only the surface layers are involved in scald injury, and the fruits remain firm in spite of a deep brown or bronze color. From 96 to 99 per cent of the untreated fruits showed the disease, and of these, from 54 to 75 per cent were classified as severely scalded (Table I).

TABLE I—THE EFFECT OF CARBON DIOXIDE TREATMENTS ON THE INCIDENCE OF STORAGE SCALD OF RHODE ISLAND GREENING APPLES (1945–46 —32 DEGREES F)

Time	Treatments*		Pressure Test Feb 7 (Pounds)	Scald in Storage Feb 7 (Per Cent)		Scald After 4 Days at 70 Degrees F (Per Cent)		Totals (Per Cent)
	Duration (Days)	Concentration (Per Cent)		Severe	Slight	Severe	Slight	
Check	–	—	13.3	34	52	54	42	96
Immediate**	3	50	15.0	16	36	32	60	92
Repeat†	3	50	15.2	1	18	1	48	49
Delayed‡. ..	3	50	14.3	10	49	26	55	81
Immediate...	3	25	14.1	15	43	39	48	87
Repeat......	3	25	14.0	1	43	11	68	79
Delay.	3	25	14.5	17	54	26	68	94
Check	–	—	12.7	41	53	75	24	99
Immediate...	5	50	14.8	5	25	1	28	29
Repeat......	5	50	14.5	0	5	3	12	15
Delayed ...	5	50	13.6	24	29	9	39	48
Immediate...	5	25	13.2	13	46	45	47	92
Repeat... .	5	25	13.8	31	59	51	45	96
Delay.	5	25	13.9	12	63	19	66	85

*Fruit harvested September 9 for 3-day treatments and September 11 for 5-day treatments.

**Fruit harvested 1 day and held over night at 32 degrees F. Treatment began following afternoon.

†Two treatments, first as under "Immediate" and second after storage in normal atmosphere at 32 degrees F for 2 weeks.

‡Fruits held in normal storage atmosphere at 32 degrees F for 2 weeks before treatment.

The percentages representing severe scald after four days are considered most significant. Treatment with 50 per cent carbon dioxide for three days immediately after harvest reduced the amount of severe scald from 54 to 32 per cent but the total scald was lowered only from 96 to 92 per cent. A second treatment after 2 weeks at the same concentration reduced total scald by half and almost entirely eliminated severe scald. In this particular experiment, delaying the treatment 2 weeks gave slightly better results. Treatment with 25 per cent carbon dioxide for 3 days gave very little control of scald.

The fruits harvested September 11 for the 5-day treatments were more susceptible to scald as indicated by 75 per cent of the check fruit being severely scalded. Treatment with 50 per cent carbon dioxide for 5 days gave almost complete control of severe scald and reduced total scald from 99 to 29 per cent. Repeating the treatment after 2 weeks reduced total scald to 15 per cent. Treatment after 2 weeks in ordinary storage resulted in a marked reduction of both severe and total scald but was not so effective as immediate and repeated treatments. Concentrations of 25 per cent gave less control of scald than 50 per cent, but the general appearance of the fruit was definitely improved in comparison with the untreated fruit. This difference was greater than can be indicated by an arbitrary system of classification unless many more gradations of injury are used.

Cortland is extremely susceptible to scald, and from 98 to 99 per cent of the untreated fruits showed some scald with at least 80 per cent classified as severely scalded (Table II). Most of the scald developed within 24 hours after exposure to room temperature of approximately 70 degrees F. Several layers of cells were involved, and after a few days, the surface of severely scalded fruits became soft. This softening of the surface tissue reduced the sales value of the fruit more than did the type of scald appearing on Rhode Island Greening.

TABLE II—THE EFFECT OF CARBON DIOXIDE TREATMENTS ON THE INCIDENCE OF STORAGE SCALD OF CORTLAND APPLES (1945–46 — 32 DEGREES F)

Time	Treatments*		Pressure Test Feb 7 (Pounds)	Scald in Storage Feb 7 (Per Cent)		Scald After 4 Days at 70 Degrees F (Per Cent)		Totals (Per Cent)
	Duration (Days)	Concentration (Per Cent)		Severe	Slight	Severe	Slight	
Check	-	—	8.6	24	36	80	19	99
Immediate**	3	50	9.0	24	18	26	49	75
Repeat†	3	50	9.9	0	5	5	15	20
Delayed‡	3	50	9.2	17	28	31	50	81
Immediate	3	25	9.1	7	22	49	50	99
Repeat	3	25	9.3	5	17	19	36	55
Delay	3	25	9.0	17	29	32	55	87
Check	—	—	8.4	19	36	83	15	98
Immediate**	5	50	9.0	0	2	1	8	9
Repeat	5	50	10.3	0	0	0	0	0
Delayed	5	50	9.3	0	7	5	15	20
Immediate	5	25	9.2	2	15	25	61	86
Repeat	5	25	9.6	0	5	2	34	36
Delay	5	25	9.9	0	16	44	45	89

*Fruit harvested September 9 for 3-day treatments and September 11 for 5-day treatments.

**Fruit harvested 1 day and held over night at 32 degrees F. Treatment began following afternoon.

†Two treatments, first as under "Immediate" and second after storage in normal atmosphere at 32 degrees F for 2 weeks.

‡Fruits held in normal storage atmosphere at 32 degrees F for 2 weeks before treatment.

One treatment with 50 per cent carbon dioxide for 3 days markedly reduced severe scald, and a second treatment reduced severe scald from 80 to 5 per cent and the total scald from 99 to 20 per cent. The delayed treatment was not quite as effective, but the fruits so treated showed less scald than the checks. Treatments with 25 per cent carbon dioxide for 3 days were less effective.

Treatments using 50 per cent carbon dioxide for 5 days gave almost complete control of amounts of scald which would affect sale of fruit. A single treatment immediately after harvest prevented more than 1 per cent severe and 9 per cent total scald. A second treatment gave 100 per cent control. With delayed treatment, scald was held to 5 per cent severe and 20 per cent total scald.

Reducing the concentration of carbon dioxide to 25 per cent gave poor results even when two treatments of 5-day duration were given. However, the reduction over untreated fruit from 83 per cent total to 25 per cent, or to 2 per cent severe scald was worthwhile. The delayed treatment with 25 per cent carbon dioxide reduced severe scald nearly half but reduced total scald very little.

McIntosh is not nearly so susceptible to storage scald as Rhode Island Greening and Cortland, but under certain conditions serious injury results. In the 1945–46 season scald on McIntosh was not severe at Kingston (Table III). One 3-day treatment with 50 per cent carbon dioxide reduced scald more than 50 per cent and a second treatment eliminated the difficulty almost entirely. Treatment with 25 per cent carbon dioxide for 3 days was not as effective as the higher concentration. None of the fruits treated for 3 days showed injury, but when treatments were continued for 5 days an injury which will be discussed later appeared near the core of some fruits especially in the repeated treatment with 50 per cent carbon dioxide.

TABLE III—THE EFFECT OF CARBON DIOXIDE TREATMENTS ON THE INCIDENCE OF STORAGE SCALD OF MCINTOSH APPLES (1945–46 — 32 DEGREES F)

Time	Treatments*		Pressure Test Feb 7 (Pounds)	Scald in Storage Feb 7 (Per Cent)		Scald After 4 Days at 70 Degrees F (Per Cent)		Total (Per Cent)	Remarks
	Duration (Days)	Concentration (Per Cent)		Severe	Slight	Severe	Slight		
Check	-	—	8 9	0	4	3	44	47	No injury
Immediate**	3	50	9.2	0	1	1	20	21	No injury
Repeat†	3	50	9.8	0	0	0	9	9	No injury
Delayed‡	3	50	9.3	0	1	3	26	29	No injury
Immediate	3	25	9.4	0	1	0	26	26	No injury
Repeat	3	25	9.7	0	0	0	16	16	No injury
Check	-	—	8.2	0	1	0	45	45	No injury
Immediate	5	50	9.1	0	0	0	9	9	1 per cent injured
Repeat	5	50	9.7	0	0	0	13	13	17 per cent injured
Immediate	5	25	9.2	0	0	0	19	19	———
Repeat	5	25	9.0	0	0	0	19	19	3 per cent injured

*Fruit harvested September 9 for 3-day treatments and September 11 for 5-day treatments.

**Fruit harvested 1 day and held over night at 32 degrees F. Treatment began following afternoon.

†Two treatments, first as under "Immediate" and second after storage in normal atmosphere at 32 degrees F for 2 weeks.

‡Fruits held in normal storage atmosphere at 32 degrees F for 2 weeks before treatment.

Baldwin showed considerable scald in the 1945–46 season ranging from 25 to 33 per cent severe and 97 to 98 per cent total in the untreated lots (Table IV). Treatment with both 25 per cent and 50 per cent carbon dioxide for 3 days greatly reduced both the incidence and the severity of scald. The higher concentration was superior to the lower concentration and prompt treatment was better than delayed treatment. Still better control of scald was secured when the time of exposure was increased from 3 to 5 days, but some injury was noticed.

TABLE IV.—THE EFFECT OF CARBON DIOXIDE TREATMENTS ON THE INCIDENCE OF STORAGE SCALD OF BALDWIN APPLES (1945–46 — 32 DEGREES F)

Time	Treatments*		Pressure Test Feb 7 (Pounds)	Scald in Storage Feb 7 (Per Cent)		Scald After 4 Days at 70 Degrees F (Per Cent)		Total	Remarks
	Duration (Days)	Concentration (Per Cent)		Severe	Slight	Severe	Slight		
Check	–	—	11.3	4	36	25	73	98	No injury
Immediate**	3	50	12.1	0	12	8	40	48	No injury
Repeat†	3	50	12.9	0	5	4	13	17	No injury
Delayed‡	3	50	12.9	0	10	10	43	53	No injury
Immediate	3	25	12.4	0	1	6	45	51	No injury
Repeat	3	25	12.8	0	13	5	30	35	No injury
Delay	3	25	12.6	1	12	15	41	56	No injury
Check	–	—	11.8	5	38	33	64	97	No injury
Immediate	5	50	15.5	0	2	1	9	10	2 per cent injured
Repeat	5	50	15.0	0	3	0	7	7	9 per cent injured
Delayed	5	50	14.7	0	5	3	11	14	2 per cent injured
Immediate	5	25	13.8	0	4	7	13	20	No injury
Repeat	5	25	13.8	0	2	3	6	9	2 per cent injured
Delay	5	25	13.5	0	6	6	17	23	No injury

*Fruit harvested September 9 for 3-day treatments and September 11 for 5-day treatments.

**Fruit harvested 1 day and held over night at 32 degrees F Treatment began following afternoon

†Two treatments, first as under "Immediate" and second after storage in normal atmosphere at 32 degrees F for 2 weeks.

‡Fruits held in normal storage atmosphere at 32 degrees F for 2 weeks before treatment.

Scald on Northern Spy, Stark, and Delicious was controlled by carbon dioxide treatments. Wealthy, Gravenstein, Jonathan, and Winter Banana showed no scald. The incidence of Jonathan spot on Jonathan was very slight in check fruit and was not appreciably affected by carbon dioxide.

A limited trial was made with Bartlett pears harvested August 25. They were exposed to 25 per cent and 50 per cent carbon dioxide for 5 days beginning September 5. Inspection in mid-December showed 64 per cent scald on untreated fruits and 5 and 13 per cent respectively for the two treatments.

Study (2) of the effect of fruit maturity on the incidence of scald confirmed a well-established belief that the more mature the apple, the less its susceptibility to the disease. In general, it was easier to control scald by carbon dioxide with properly matured than with green fruit.

Definite carbon dioxide injury resulted from exposure of overripe Duchess and Yellow Transparent apples to 60 per cent carbon dioxide for 6 days. The damage was evident in the browning of the core tissue and some areas directly under the skin, similar to the injury described by Thornton (6).

A different kind of injury was observed with McIntosh and Baldwin. It consisted of corky pockets of brown tissue close to the core of the fruit. The injury was not the same as the cork which we recognize as due to boron deficiency. Whereas almost all Duchess and Yellow Transparent fruits were affected in the above mentioned treatments, only a few apples of McIntosh and Baldwin were involved. This injury was observed for the most part in the boxes close to the steel drums with Dry Ice where some freezing of the fruit occurred. Since this difficulty was experienced under conditions reported safe by other investigators (6) the authors reserve judgment as to the true nature and cause of this phenomenon.

It should be emphasized that no visible carbon dioxide injury to the flesh and no effect on flavor was observed with the following varieties: Cortland, Rhode Island Greening, Northern Spy, Delicious, Jonathan, Stark, Winter Banana, Gravenstein, and Wealthy.

An examination of the tables will show that in every case the treatments with carbon dioxide resulted in firmer fruits as measured by pressure test. This increased firmness means a longer storage period for the fruits concerned.

Two experiments were arranged to give data on the approximate cost of carbon dioxide treatments for scald control. A cold room of 8500 cubic feet capacity was used in both cases.

A ton of dry ice was brought in on February 7. Four hundred pounds was broken into small pieces and spread on the floor, and the remaining 1600 pounds packed in a steel lined box provided with a window 1 foot square. Since the room was cooled by overhead brine pipes, a small electric fan was provided to increase air circulation and to prevent stratification of the gas.

The concentration of carbon dioxide rose within a few hours to 35 per cent and stayed almost constant for 3 days. At the end of this period, the room was opened, and the remaining dry ice taken out and weighed. The weight was found to be 1070 pounds. An atmosphere of 35 per cent carbon dioxide was maintained in a room 8500 cubic feet in volume with 930 pounds of dry ice. The cost of the treatment amounted to about $3.25 per 1000 cubic feet at a price of 3¢ per pound for the dry ice.

On February 11, another ton of dry ice was disposed in this room in a similar way. The top of the box was taken off, and a second electric fan was placed near the box to increase the evolution of the gas. The purpose was to maintain an atmosphere of 50 per cent carbon dioxide as long as possible. The concentration of the gas rose to 44 per cent within a few hours after the door was closed. The room was kept sealed for a week. The concentration of carbon dioxide decreased gradually until it reached 25 per cent at the end of one week. When the door was opened there were 360 pounds of dry ice left in the box. The dry ice actually used cost $49.20. It is believed that with better methods of speeding evolution of carbon dioxide from dry ice one ton would be enough to provide an atmosphere of 50 per cent of this gas for 5 days in the room used. Assuming that the room is filled with 3300 bushels of fruit the cost of the dry ice would be less than 2¢ per bushel.

Additional work must be carried on to determine the best means of providing proper concentrations of carbon dioxide in a cold storage room. The metal-lined box for holding a reserve of dry ice was found impractical because it restricted evolution of the gas.

Discussion

Storage scald of apples was very severe in 1945–46. Check fruit of susceptible varieties in storage showed considerable scald early in February, with the discoloration reaching almost 100 per cent after the fruits were exposed for a few days to room temperature.

It was more difficult to control scald by the carbon dioxide treatment in 1945 than in 1944 (3, 4). Whereas a 3-day exposure to 30 per cent carbon dioxide gave excellent control of scald in 1944, a 5-day exposure to 50 per cent carbon dioxide was necessary to give equivalent control in 1945–46. Some treated fruit showed scald, but the severity of the disease was much less than with the checks. Differentiation into "severe scald" and "slight scald" is, of course, arbitrary. The fruits "slightly scalded" had in fact only a trace of the disease and were of good market quality.

Repeated treatments had a cumulative effect, but a single five-day treatment with 50 per cent carbon dioxide was always superior to two treatments at the same concentration for 3 days each. Treatments given after a 2-week delay at 32 degrees F were almost as effective as those applied immediately after picking. The wide range of conditions under which carbon dioxide is effective is encouraging since whatever expense is incurred in treatment will be offset by improvement in the quality of the fruit.

Summary

Storage scald of apples was controlled by exposing freshly harvested fruit to high concentrations of carbon dioxide for a few days in a cold storage room. Five-day treatment with 50 per cent carbon dioxide appeared most practical and gave satisfactory results.

Treatments with carbon dioxide resulted in a delay in the ripening of the fruit which would lengthen the storage period.

Some injury was observed with the Baldwin and McIntosh varieties. The nature and cause of injury was not finally determined. No injury was observed with Cortland, Rhode Island Greening, Northern Spy, Stark, Delicious, Gravenstein, Winter Banana, Wealthy, and Jonathan. The treatment, however, is not recommended for general commercial application until safe limits of effective carbon dioxide concentrations can be established and better methods of gas dispersal developed. Encouraging results were also obtained with Bartlett pears.

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Some Problems Involved in Securing an Accurate Measure of the Cold Resistance of Dormant Buds of Different Varieties of Peaches

By M. A. Blake, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

The low temperature resistance of dormant fruit buds of the peach is of much practical concern to growers, peach breeders, and pomologists in general. Until comparatively recently, however, there was no method available by means of which one could make cold hardiness tests at will that would be at all comparable with conditions in the orchard. The common practice has been to select and section a certain number of fruit buds of one or more varieties of peaches following a night when the temperature was below zero and to note the percentage of buds remaining alive. If variety A had a higher percentage of buds alive than B it was considered hardier than B, regardless of the concentration of the bud set of each variety.

In 1940 and 1941, a method for freezing dormant fruit buds of the peach to determine their relative winter hardiness was developed at the New Jersey Agricultural Experiment Station (1). Reports of later studies have since appeared (2, 3). During each winter since the freezing method was developed, the fruit buds of many named varieties and those of an even larger number of unnamed varieties from known crosses have been tested for cold resistance.

Perhaps the first fundamental which should be emphasized is the fact that the cold resistance of a dormant peach bud is really centered in a very small mass of tissue consisting of the pistil. In general, this mass of tissue is more sensitive to injury by cold than is leaf bud or twig tissue. But that is not always true. Peach twigs sometimes exhibit considerable low temperature injury and yet a high percentage of the fruit buds remain alive. In this paper, low temperature resistance is presented only with respect to the fruit bud.

It is a well established fact that as soon as a peach bud starts to develop or emerge from its most dormant state it loses resistance to low temperature. The buds of one variety of peach, however, may be in a more advanced stage of development than another and still be more resistant to cold. In other words, relative resistance of different varieties to cold cannot always be measured by the stage of bud development. One variety of peach may have a higher percentage of buds alive at one temperature than another but the reverse may be true at a different temperature. It is still not very generally known that fully dormant peach buds fluctuate from day to day with any marked change in temperature, as previously reported (2).

Another well established fact is that the rate of drop in temperature has a very marked effect on the severity of bud injury. All hardiness ratings of varieties at New Brunswick are based on the same method of exposure to cold. In general, the rate of drop in temperature to which the buds are subjected has been relatively slow, or less than 3 degrees F per hour.

The dormant fruit buds of each variety of peach commonly exhibit a wide range in hardiness. A certain percentage in each case will prove tender, some medium hardy, others hardy, and still others may be very hardy. Even such a variety as Aurora, which may be classed as tender, may experience a bud kill of 91 per cent and still have enough buds per twig remaining alive to produce a good crop (3). A bud set of 45 buds per foot, however, is very unusual for a commercial variety.

Taking these and other factors into consideration, certain procedures are followed at New Brunswick in determining the resistance of the peach buds of different varieties to low temperatures. A minimum sample of buds of any variety for a cold resistance test consists of 200 to 250 buds. This is obtained by selecting about 20 to 25 9-inch sections of 1-year-old twigs of a variety. Bud samples smaller than this have been found to be too variable and not representative enough.

To measure the cold resistance of new varieties, it is necessary to include several varieties whose hardiness has been established, or criterion varieties, in each freeze. At least three classes of hardiness, namely, very hardy, hardy, and medium hardv, should be represented. The relative resistance of seven varieties to low temperatures on six different dates in 1944 is given in Table I to show what variations in hardiness do occur and, therefore, the need for several criterion varieties in each test.

The results of six freezes, made from January 25 to February 3, 1944 inclusive, were selected for this illustration since on five different dates the buds were exposed to —9 degrees F and yet each of the several criterion varieties were as hardy or hardier on February 3 than they were on January 25.

Elberta and J. H. Hale are medium hardy varieties in New Jersey. Hiley is only slightly hardier. Golden Jubilee and Cumberland are both hardy. Although Rosebud is consistently very hardy at New Brunswick, in the tests reported on January 25 and 27, 1944, it was less hardy than either Elberta or J. H. Hale which are commonly only medium hardy. In the next four freezes reported on January 31 and February 1, 2, and 3, however, it resisted the low temperatures better than any of the other six varieties. In all but one of twelve additional freezes conducted during February, Rosebud was hardier than either Golden Jubilee or Cumberland.

If these criterion varieties had been exposed to only one freeze on February 1, Greensboro would have appeared to be less hardy than any of the other varieties except J. H. Hale but we know that at most times it is definitely hardier. In the tests for which data are supplied in Table I Golden Jubilee is an example of a consistently hardy variety while Elberta and J. H. Hale are examples of varieties which fluctuate considerably.

THE SIGNIFICANCE OF CONCENTRATION OF BUD SET

The mere percentage of live buds upon a peach tree following a freeze may be of but little practical value. What is important is the

TABLE I—RESISTANCE OF CRITERION VARIETIES OF PEACHES TO LOW TEMPERATURES AT NEW BRUNSWICK, NEW JERSEY IN 1944

Date	Frozen to Degrees F	Outside Temperature in Degrees F.		Percentage of Buds Alive						
		Maximum	Minimum	Greensboro	Cumberland	Golden Jubilee	Rosebud	Hiley	J. H. Hale	Elberta
Jan 25	−9.0	47	20	47.1	51.8	76.4	31.2	42.7	38.1	39.1
27	−9.0	62	30	38.0	41.8	30.7	11.7	14.5	13.1	3.7
31	−9.0	40	18	33.3	40.2	43.4	67.4	25.9	9.8	3.0
Feb 1	−9.0	50	31	18.3	40.0	38.1	71.2	27.6	13.3	31.4
2	−9.0	67	32	68.5	70.7	73.4	89.1	40.0	36.6	51.4
3	−9.5	37	28	50.5	50.4	43.9	80.6	12.2	42.5	10.3
Average				42.6	49.2	51.0	58.5	27.2	25.6	23.2

number of live buds per foot of annual growth. Peach twigs selected for freezing tests at New Brunswick are cut to a length of 9 inches. The number of live and dead buds remaining after each freeze is recorded by twigs. It is possible, therefore, to record the results of a freeze both in terms of percentage of total buds alive and the average actual number of buds alive per 9 inches of twig growth. Table II is included to illustrate the comparative value of each method of recording results.

TABLE II—RESISTANCE OF PEACH BUDS TO COLD ON BASIS OF PERCENTAGE ALIVE COMPARED TO THE NUMBER ALIVE PER TWIG

Variety and Source*		Percentage Buds Alive at Four Temperatures (Degrees F)				Average Bud Set	Average Number Buds Alive (Degrees F)			
		−5	−6	−7	−8		−5	−6	−7	−8
Cumberland	AF	60.7	45.2	22.1	20.8	16.3	9.9	7.4	3.6	3.4
Elberta	HF	48.4	36.0	25.6	17.3	7.0	3.4	2.5	1.8	1.2
Fireglow	AF	40.6	34.0	14.5	10.0	9.3	3.8	3.2	1.3	0.9
Golden Jubilee	AF	51.1	50.2	30.8	17.8	14.2	7.2	7.1	4.4	2.5
J. H. Hale	HF	51.8	21.5	14.0	6.2	8.6	4.5	1.9	1.2	0.5
Triogem	AF	58.5	47.5	22.3	20.2	11.1	6.5	5.3	2.5	2.2

*AF = Adams' Farm; HF = Horticultural Farm.

As shown in Table II, the fruit buds of six varieties of peaches were exposed to four different low temperatures on January 7, 1946. At −5 degrees F Golden Jubilee had the same percentage of buds alive as J. H. Hale, and Elberta almost as high a percentage. Yet on the basis of number of buds remaining alive per twig, Golden Jubilee had an average of from three to four more buds than Elberta and from two to three buds more than J. H. Hale.

At −6 degrees F Golden Jubilee still had seven buds remaining alive per twig but J. H. Hale had only about two and Elberta between two and three.

At −8 degrees F Golden Jubilee and Elberta had about the same percentage of buds alive but Golden Jubilee averaged more than two buds per 9-inch twig while Elberta averaged about one bud per twig and Cumberland averaged more than three buds per twig. Cumberland

and Triogem resisted −8 degrees F almost as well as they did −7 degrees F.

Only very small representative samples of data already obtained at the New Jersey Station have been presented here. It will serve, however, to demonstrate the complexity of the problem when seeking evidence as to the relative hardiness of even the dormant buds of new peach varieties.

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The Use of Carbon Dioxide for Controlling Rodents in Cold Storage Rooms[1]

By S. A. PIENIAZEK and E. P. CHRISTOPHER, *Rhode Island State College, Kingston, R. I.*

THE control of rats and mice in apple storage has been the subject of recent research (2, 6). Methyl bromide was found to be satisfactory as a means of controlling rodents, but since it is a poisonous gas, great care must be exercised when using it. Special equipment is necessary, and there is evidence that the gas may cause damage to plant tissues under certain conditions (1, 3).

In Rhode Island the problem of rodent control has been investigated along with studies of carbon dioxide upon the development of scald on apples (4, 5). The use of high concentrations of carbon dioxide may offer a relatively safe and cheap method of controlling both scald and rodents in cold storage rooms.

METHODS AND MATERIALS

The rats and white mice used in these experiments were secured from F. B. Schuler, U. S. Fish and Wild Life Service, Storrs, Connecticut, and from the White Animal Farm located at Pine Point, Maine. The rodents were kept in wire cages at room temperature until needed. In the initial experiments, test rodents were kept in the 32 degree F storage room for 1 hour before treatments began (2). Later experience demonstrated that this period was not sufficient for acclimation and in subsequent tests the animals were held for a period of at least 2 weeks at storage temperature before differential treatments were begun. The rodents were placed in small wire cages with sufficient litter to keep the animals off the wire. They were exposed to gas treatment in 55-gallon steel drums in the preliminary tests and later in storage rooms. Carbon dioxide was supplied from cylinders of compressed gas or in the form of Dry Ice. Samples of the gas mixture were taken from time to time and the carbon dioxide concentration determined by noting the change in volume when the carbon dioxide has been absorbed by sodium hydroxide.

RESULTS

The first studies were made in April 1945 using barrel containers and rodents subjected to cold for 1 hour before treatment. These tests sought an answer to the question of necessary concentration. White mice exposed to concentrations of 15 and 25 per cent carbon dioxide died in from 45 to 90 minutes. Norwegian rats after being treated with 12 and 15 per cent carbon dioxide died in from 2½ to 6 hours. Table I gives average figures for the length of time required for the gas to cause death.

It will be noted that the *Norwegian rats are much more difficult to*

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TABLE I—THE EFFECT OF VARYING CONCENTRATIONS OF CARBON DIOXIDE UPON RODENTS AT 32 DEGREES F

Concentration of CO_2 (Per Cent)	Rodent	Sex	Number of Rodents	Average Time Required to Kill (Minutes)
25	White mouse	Male	3	48
	White mouse	Female	2	45
15	White mouse	Male	5	83
	White mouse	Female	5	55
15	Norwegian rat	Male	3	210
	Norwegian rat	Female	3	170
12	Norwegian rat	Male	2	330
	Norwegian rat	Female	2	285

kill than the white mice. It will be observed that the *males are less sensitive* than the females to the influence of carbon dioxide as has been reported previously with methyl bromide (6). While the number of animals involved was not great, the uniformity of the data is convincing.

Following these initial tests, one white mouse died in cold storage without being subjected to gas treatment. While the cause of death is not known, this occurrence raised the question of acclimation. On June 19, two male rats which had been maintained at 32 degrees F for at least 2 weeks and three male rats from the laboratory were placed in a cold storage room of about 8500 cubic feet capacity and subjected to a carbon dioxide concentration of 19 per cent. Dry Ice was used as the source of carbon dioxide. After 4 hours, the three rats from the laboratory were dead but the pretreated animals were alive. After 14 hours exposure during which time the carbon dioxide concentration had dropped to 12 per cent, these acclimated rats were dead also.

Under usual storage conditions, there will be a period ranging from

TABLE II—EFFECT OF PRIOR TEMPERATURE CONDITIONS UPON THE KILLING OF RATS* BY CARBON DIOXIDE GAS AT 32 DEGREES F

Rat	Concentration of CO_2 (Per Cent)	Previous Treatments	Effect
1	11	Non-acclimated	Dead 4 hours
2	11	Acclimated	Alive after 5 hours
3	15	Non-acclimated	Dead 5 hours
4	15	Non-acclimated	Dead 4 hours
5	15	Acclimated	Alive after 24 hours
6	15	Acclimated	Alive after 24 hours
7	15	Non-acclimated	Dead 5 hours
8	15	Non-acclimated	Dead 5 hours
9	15	Acclimated	Dead 10 hours
10	15	Acclimated	Alive after 24 hours
11	20	Non-acclimated	Dead 3 hours
12	20	Non-acclimated	Dead 4 hours
13	20	Non-acclimated	Dead 4 hours
14	20	Acclimated	Dead 5 hours
15	20	Acclimated	Dead 5 hours
16	20	Acclimated	Dead 3½ hours
17	20	Non-acclimated	Dead 3 hours
18	20	Non-acclimated	Dead 1¾ hours
19	20	Acclimated	Dead 3 hours
20	20	Acclimated	Dead 4 hours

*All rats used in these tests were males.

a few days to a few weeks in which the rodents can become acclimated before control measures are undertaken. It is necessary, therefore, to know of any increased resistance to control procedure induced by acclimation. In an effort to determine the importance of this factor, rodents were secured and further tests made during August.

As was indicated by the results of the preliminary tests, acclimation of the rodents usually increased the time needed to bring about death although rodents always died at the higher concentrations (Table II). At the same time eight white mice which had been acclimated died by the end of from 1¼ to 2½ hours when exposed to a carbon dioxide concentration of 12 per cent. A similar group of non-acclimated mice lived from 1 to 2 hours.

Since workers using methyl bromide did not include any data on a long period of acclimation, it was thought desirable to check their work. Therefore, 10 male rats were exposed singly to methyl bromide for 4 hours at the recommended concentration of ¼ pound per 1000 cubic feet of air. Half of them had been acclimated and half had not All except one died within 6 hours. The single exception survived for 48 hours and was able to eat during that period, but finally died. All of one lot of 12 mice died within 4 hours even though half of them were acclimated. Apparently treatment at this concentration for 4 hours was severe enough to cause death regardless of previous conditioning.

Four acclimated adult rats were exposed to a concentration of ⅛ pound methyl bromide per 1000 cubic feet for 6 hours and all died. When four similar rats were exposed for 3 hours, three died and one recovered. Four non-acclimated rats when given the same treatment died within 24 hours. It would appear that this concentration was close to the lower limits which could be expected to give 100 per cent kill of acclimated rats. It seems reasonable to believe that the concentration secured under our experimental conditions would be more uniform and constant than those obtained in a storage filled with fruit. It would appear that the recommendation of one-fourth pound methyl bromide per 1000 cubic feet for 4 hours is the lowest satisfactory recommendation.

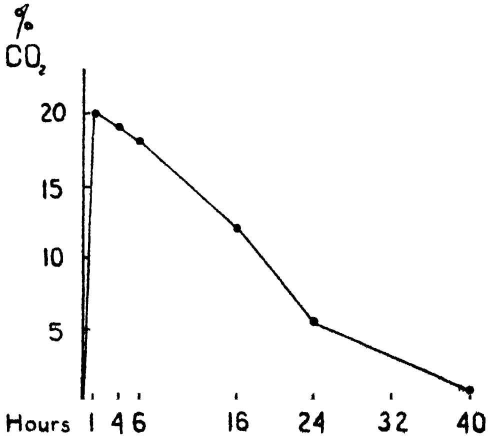

FIG. 1. Carbon dioxide in storage room at intervals after introduction of dry ice (8500 cubic foot capacity — 225 pounds dry ice).

Dry ice seems to be the most practical means of securing the desired concentration of carbon dioxide. Approximately 123 pounds of Dry Ice are necessary to produce 1000 cubic feet of gas. Using a storage room of approximately 8500 cubic foot capacity, 225 pounds of dry ice gave more than sufficient gas (Fig. 1).

This test was made in August before any volume of fruit occupied the space. The amount of dry ice used maintained a concentration of at least 15 per cent carbon dioxide for 10 to 12 hours. Six adult rats and seven adult mice, all acclimated, were in the room during the test and all were found dead the following morning.

Tests in connection with the work on scald control have shown that the smaller the room the more difficult it is to maintain high concentrations of carbon dioxide unless special gas proofing is practiced. It has been found possible to maintain as high as 50 per cent concentration for several days, however, and the concentration necessary to control rodents could be very easily obtained. At present Dry Ice can be obtained for 3 cents a pound. The cost of treating this storage room with a non-poisonous gas would be less than 7 dollars or about ⅕ of a cent per bushel if the storage were filled to capacity.

CONCLUSIONS

Carbon dioxide at a concentration of about 20 per cent will kill rats and mice in storage at 32 degrees in 3 to 5 hours. Rodents which have been previously subjected to low temperature for a period of time are more difficult to kill than those whose resistance has been lowered by a sudden temperature change. Methyl bromide at the recommended concentration of ¼ pound per 1000 cubic feet for 4 hours will kill both acclimated and non-acclimated rodents. From limited trials, it would appear that 25 to 30 pounds of dry ice per 1000 cubic feet storage capacity would be sufficient to kill rodents. With carbon dioxide there is no need for any equipment other than an ordinary fan to speed gas liberation. Carbon dioxide under these conditions will not injure fruit and can be handled by men without gas masks and with no danger if simple precautions are followed. There are indications from studies on apple scald that rodents and scald can be controlled simultaneously by treatment with carbon dioxide.

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The Effect of Different Post-Storage Temperatures on the Firmness and Condition of Richared Delicious[1]

By I. C. HAUT, *University of Maryland, College Park, Md.*

THE study herein reported was undertaken to determine the effect of different temperatures on the loss of firmness and quality of apples during post-storage periods simulating distribution and retail marketing conditions.

MATERIALS AND METHODS

The Richared Delicious used in these studies were obtained from a block of 7-year-old trees growing on the Maryland Plant Research Farm. The fruit was harvested on September 16, 1945 with an average pressure test of 15.4 pounds. Well colored fruits grading 2¾ to 3¼ inches were carefully selected, placed in standard bushel baskets and stored immediately in a cold storage room maintained at a temperature of 30 to 31 degrees F and a relative humidity of approximately 80 per cent.

Following 2½ and 4 month periods of storage, samples of fruits were removed and placed in constant temperature chambers maintained at 45, 55 and 65 degrees F with relative humidity between 75 and 85 per cent.

Preliminary determinations employing 45 and 65 degrees F temperatures and 4-day intervals between tests had indicated the desirability of a third intermediate temperature and shorter intervals between tests. Consequently, the three temperatures were employed as indicated with 2-day intervals between tests.

Fifteen fruits constituted a sample for the determination of firmness and per cent mealy fruits. Firmness was evaluated by a King pistol-type pressure tester using a standard 7–16 inch plunger. Mealiness was evaluated organoleptically. No attempt was made to evaluate degrees of mealiness; however, it was found necessary to allow fruits from the different lots to attain approximately the same temperature before testing in order to record slight degrees of mealiness with consistency. Determinations were continued at two day intervals for the total period indicated in Figs. 1 and 2.

RESULTS AND DISCUSSION

The results are graphically presented in Figs. 1 and 2. Following 2½ months of cold storage (Fig. 1), the loss in firmness at the subsequent holding temperature of 45 degrees F averaged 0.14 pounds per 2-day interval or 1.22 pounds for a period of 18 days. At 55 degrees F this loss averaged 0.48 pounds per interval and 4.37 pounds for the total period, and at 65 degrees F these losses were 0.52 pounds and 4.66 pounds respectively. After 4 months of cold storage

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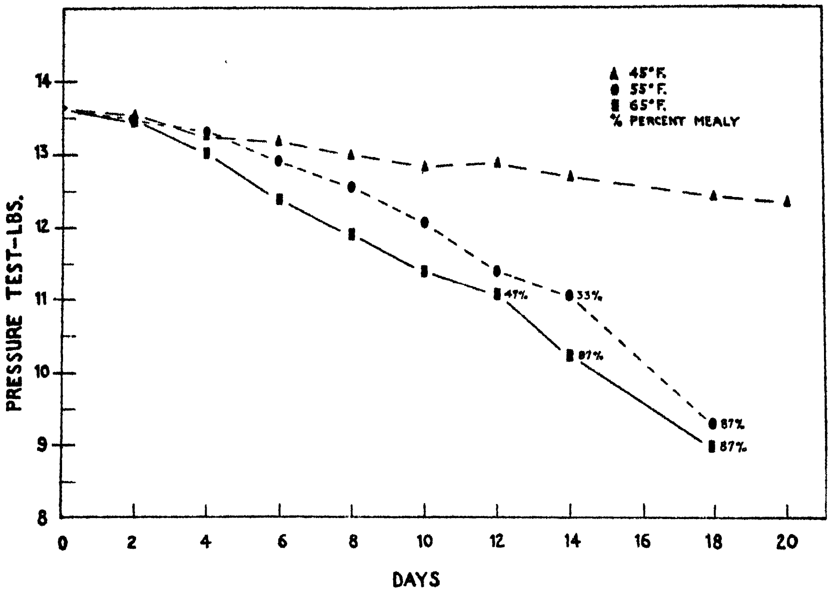

FIG. 1. Loss in firmness and development of mealiness upon holding for intervals at three post-storage temperatures following 2½ months of cold storage.

similar losses occurred (Fig. 2) at these post storage temperatures, substantiating the earlier results.

These data further indicate that some mealiness was evident in all samples when an average pressure test approximating 11 pounds was

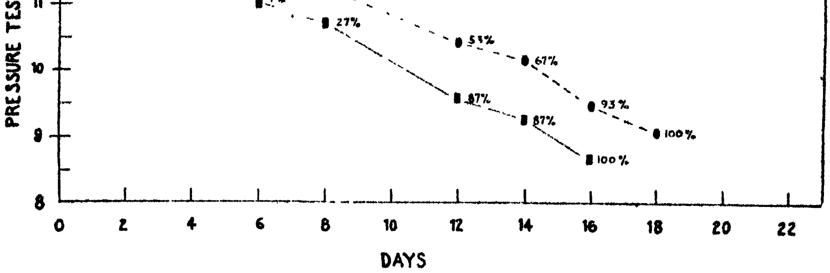

FIG. 2. Loss in firmness and development of mealiness upon holding for intervals at three post-storage temperatures following 4 months of cold storage.

reached. Below this figure mealiness increased rapidly with progressive decreases in firmness with all samples showing 80 per cent or more mealy fruits when the average pressure test fell below 10 pounds.

These findings are regarded as particularly pertinent in relation to post-storage handling and marketing. Until firmness drops to an average pressure test of 11½ pounds, it would appear that Delicious could be subjected to temperatures as high as 45 degrees F for reasonable periods of time, whether in transit, refrigerated cabinets, vending machines or during household refrigeration, without an unduly rapid loss in firmness or the excessive development of mealiness. Conversely, the behavior of this variety when subjected to post-storage temperatures of 55 or 65 degrees F indicates clearly the effect of these temperatures in rapidly reducing firmness and quality when prevailing for more than a few days during distribution or marketing. The wide differences in behavior of the fruit between the 45 and 55 degrees F temperatures also indicates the need for more critical studies in this temperature range. Changes in rates of respiration and in soluble pectin accompanying such studies would be valuable in interpreting results.

The Value of Stone Markings in Peach Varietal Identification

By M. A. BLAKE and L. J. EDGERTON, *New Jersey Agricultural Experiment Station, New Brunswick, N. J.*

THE bony pericarp or stone of the peach varies greatly in size, form, and surface markings among different varieties. In the past, these stone characters have not been utilized for the purpose of varietal description and identification to the extent that their importance would seem to justify. An early attempt at utilizing these characters was made by Wilkins in 1885 (2). He based a study of the genetic relationships between the peaches of the Fergana Valley in Asia and the almond on the surface markings of the stones. More recently, in 1932, Kostina and Ryabov (1) used the size, shape, and surface markings of the stones in comparing and describing varieties from the Fergana Valley.

It is not possible to discuss all of the stone characters of the peach in a short paper. Therefore, the discussion here will be limited to the stone markings.

SURFACE MARKINGS

When many species, types, and varieties of peaches are considered, the more prominent markings on the stone range from round depressions or pits to long, deep grooves. Numerous combinations of these are found on different varieties. As a basis for the study of stone markings, eight major forms are recognized. These are presented in Table I along with representative varieties of each class. These markings are illustrated by stones of the representative varieties in Fig. 1.

Two minor types of surface markings are sometimes found on peach stones. These may be described as (a) etched, and (b) honeycombed. Stones showing these markings are illustrated in Fig. 2. The rough, granular appearance of the surface of Shalil is characteristic of stones with an etched surface while the fine pin point, slightly cupped depressions on the surface of the Radiance stone gives it a honeycombed appearance on certain areas. These two forms of markings occur frequently enough in some degree among American varieties to be of value for identification purposes.

Most of our common varieties of peaches are characterized by more

TABLE I—CLASSIFICATION OF SURFACE MARKINGS OF PEACH STONES

Class	Description	Representative Variety
1	No prominent markings	P. Mira
2	Single pits	Amarillo Tardio
3	Groups or rosettes of pits	Slappey
4	Chains of pits	Late Crawford
5	Pit grooves	Late Crawford
6	Line grooves	Ferganensis
7	Forked grooves	P. davidiana
8	Long, branched grooves	Shalil

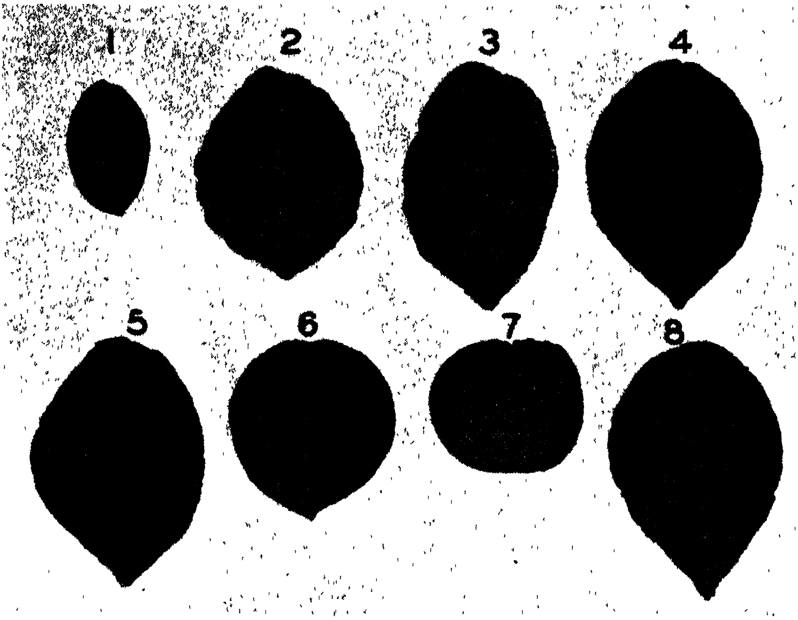

FIG. 1. Peach stones illustrating various surface markings. (1) No prominent markings; (2) single pits; (3) rosettes of pits; (4) chains of pits; (5) pit grooves; (6) line grooves; (7) short forked grooves; (8) long branched grooves.

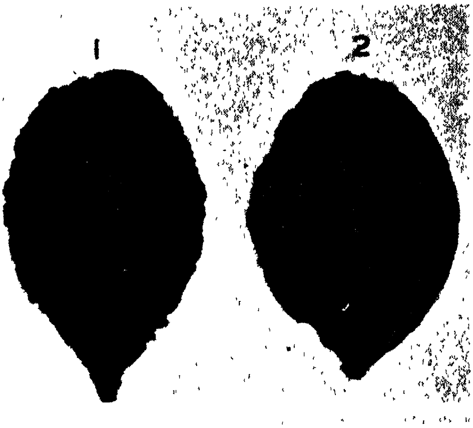

FIG. 2. Peach stones showing two minor surface markings. 1. etched (Shalil). 2. Honeycombed (Radiance).

than one type of marking on the body of the stone and along the suture. The combination of these markings may appropriately be termed the pattern. It should be noted that the patterns of the two sides of a stone commonly vary slightly. In making comparisons between stones of different varieties, therefore, the same relative side of the stone should be viewed. In the discussion which follows of the stone patterns of European and Chinese Cling type varieties, both sides of the stone are considered and the illustrations in Fig. 3 show the two views. The ventral suture is at the left in the upper row and at the right in the lower row of each line of pits A and B. In comparing the stones of different types or varieties it should also be noted that the flatness or plumpness of the stone may modify the appearance of the pattern along the sutures.

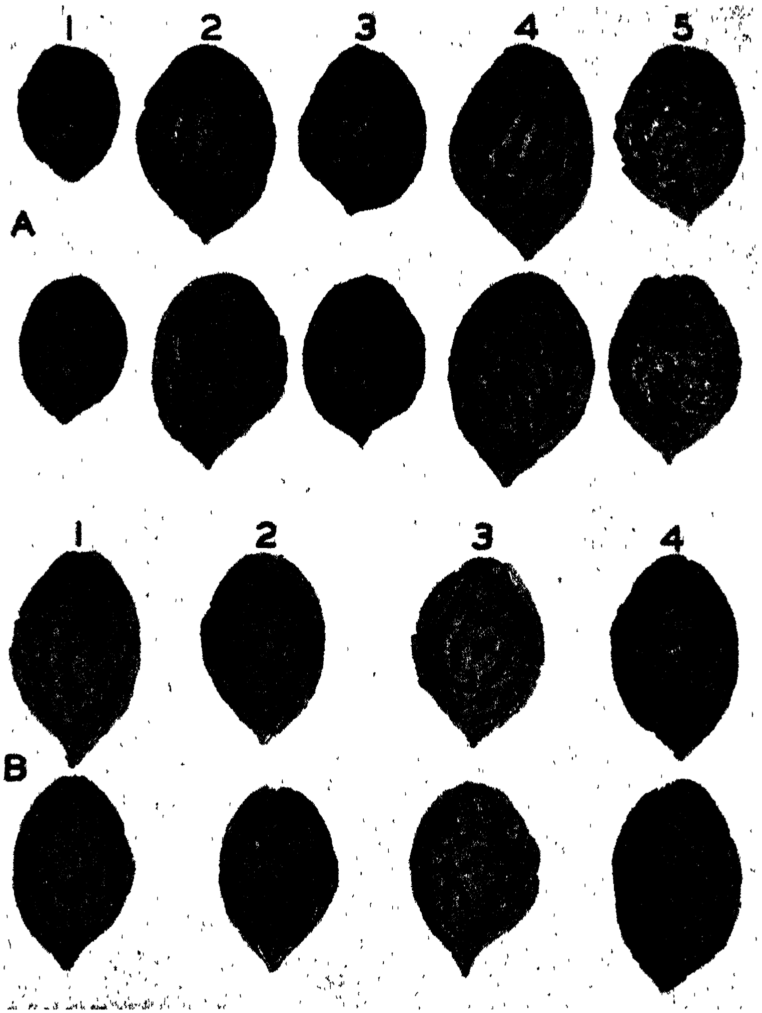

Fig. 3. Peach stones illustrating various marking patterns of a few representative varieties of the European (A) and Chinese Cling (B) types. A—1. Red Magdalen, 2. Alberge, 3. Early Crawford, 4. Late Crawford, 5. Dewey.
B—1. Chinese Cling, 2. Hiley, 3. Carman, 4. Slappey.

EUROPEAN AND CHINESE CLING PATTERNS

Since our common varieties of peaches have originated, either directly or indirectly, from the European or the Chinese Cling types, the stone pattern of a few representative varieties of these two types are shown in Fig. 3. Red Magdalen and Alberge have been selected as representative of the old European type. Early and Late Crawford are selected as representative of early American varieties which developed from the European type. One may note from Fig. 3 that the markings on Early Crawford closely resemble those of Alberge. The chief difference between the stones of these two groups of varieties is that those of Red Magdalen and Early Crawford are smaller, and the grooves and pits are less deep and coarse than in the other two. The most common pattern of the European varieties is characterized by a series of numerous, shallow grooves radiating from the base. Beyond these grooves toward the center of each stone are pits and chains of pits which rather often become deep grooves across the body of the stone. Illustrations of Dewey stones are included merely to show a variation of the European type where the markings consist almost entirely of pits with only a limited number of very short grooves.

The pattern of markings on the stones of the Chinese Cling, in contrast to the European pattern, consists of only a few grooves at the base, a relatively smooth central body, and only a few short grooves and scattered pittings at the apex. There are also wide grooves or "valleys" along the dorsal suture. It will be noted that the markings on the stones of Hiley closely resemble those of Chinese Cling. Carman has more deep pittings than Chinese Cling and a few more short, deep grooves. The stones of these three varieties are characteristically plump. Slappey is a rather distinct variation of the Chinese Cling type because of its flat shape, very numerous pittings, and relatively few short grooves.

MIXED PATTERNS

The stones of Belle, Elberta, and Hale, as illustrated in Fig. 4, show various combinations of markings and forms common to both the European and Chinese Cling. The stones of Belle tend to be rather uniformly elliptical and relatively flat, as compared to Chinese Cling, with very few grooves at the base. There are more short grooves and small, shallow pits across the body of the stone. The numerous, prominent grooves near the apex resemble the European pattern.

The Elberta pattern shows somewhat more variation from the Chinese Cling than Belle, having deeper, longer, and more pronounced grooves at the base, and a prominent bulge along the ventral side similar to the European type. The apex is also more prominently marked with grooves than Chinese Cling.

J. H. Hale even more markedly resembles the European pattern, particularly that of Late Crawford. There are fewer chains of pits, however, and the grooves at the apex tend to be fewer in number than in the typical European pattern. The ventral suture is more deeply notched than that of Chinese Cling.

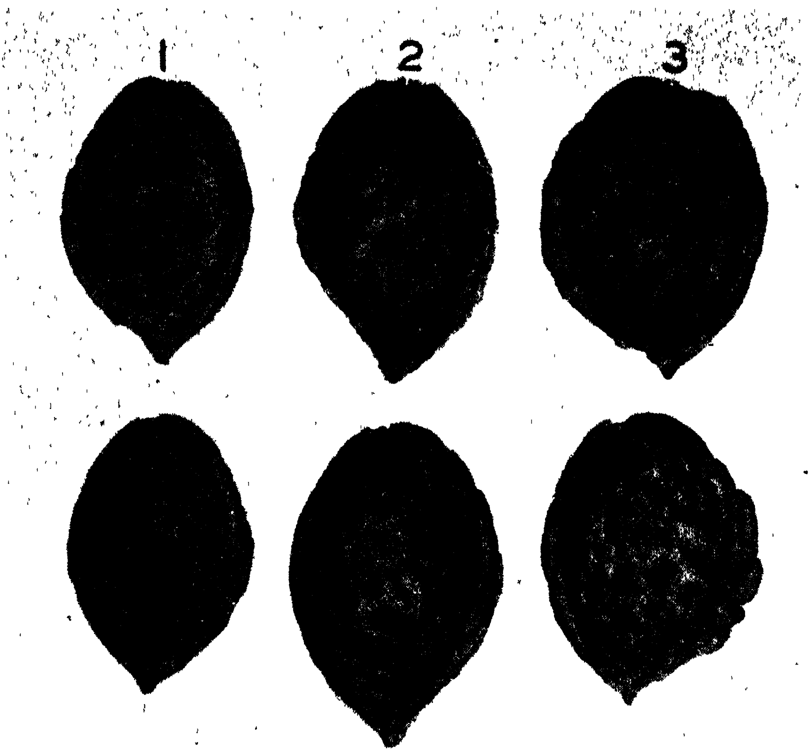

FIG. 4. Peach stones illustrating combinations of form and marking patterns between the European and Chinese Cling. 1. Belle, 2. Elberta, 3. Hale.

These illustrations indicate how the stone patterns and markings of peaches may present valuable evidence as to the parentage of a variety.

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Treatment of Peach Seed with Fungicides for Increased Germination and Improved Stand of Peach Seedlings in the Nursery

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SEEDS of peach (*Prunus persica* Batsch) frequently mold, both during the stratification process and when planted in the soil. Reports of nurserymen, as well as previous experiments (1), have shown that germination is reduced greatly by decay of the seed, which is more pronounced during wet and cold springs unfavorable to germination. Initial experiments in treating peach seed with fungicides have increased the percentage germination. This paper presents data on treatments of peach seed with various fungicides under different conditions, including treatment of the entire pit and the separated seed, both before and after after-ripening. Throughout this paper, the term "seed" is used to denote the seed separated from the stony pericarp, whereas the term "pit" refers to the seed plus the enclosing stony pericarp.

MATERIALS AND METHODS

Since Lovell and "Natural" peach seeds are widely grown as understocks, these varieties were used extensively in the tests. The Salwey variety was also used to a limited extent. Six commercial fungicidal preparations, Arasan, Ceresan, Fermate, Semesan, Spergon and Zerlate, several of which are frequently used in preventing decay of germinating seeds, were recommended for trial by the Department of Plant Pathology.

The presence of the stony pericarp necessitated some means of getting the fungicide into direct contact with the enclosed seed. Therefore, in treating the pits, two methods were employed. In one, the pits were submerged in aqueous solutions of the fungicides in a 200 mm dessicator for 30 minutes and the air exhausted by means of a water pump (2). In the other method, the pits were soaked for 20 hours in the solutions. Treatment of the seeds, after cracking of the pit and removal of the stony pericarp, consisted in dusting with dry powder preparations of the fungicides. The most effective means of dusting, which insured a thin film of powder over the entire surface of the seed, was by shaking the seeds and a small amount of powder together in a paper bag. When treatment was made before after-ripening, the pits and the seed were stratified subsequently in peat moss or sand; when proper after-ripening had occurred, they were planted in soil in flats to germinate. In other cases, when pits and seed had been both partially and fully after-ripened before treatment, seeds were dusted and directly planted in soil.

RESULTS

Experiment 1:—Six hundred peach pits of Lovell and "Naturals", 25 in each lot, were stratified in peat moss at weekly intervals for 12 consecutive weeks and removed on the same day at the end of that time. Stratification was begun January 24, 1945, and ended April 18, 1945. The pits were removed from the peat moss and cracked, and 300 of the seeds were dusted with Semesan, Arasan, Spergon, Fermate, and Ceresan in the manner described above. That is, as Table I indicates, each weekly interval of stratification (1 to 12 weeks) was treated with the fungicides in the order named. The remaining 300 seeds were left as controls. Both treated and untreated seeds were then planted in flats in regular soil mixture, and kept on the greenhouse bench at 65 degrees F to germinate.

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[1] The work reported in this paper was done largely while the author was with the N. Y. State Agricultural Experiment Station, Geneva, N. Y.

Although some germination will occur as early as the third week of stratification (1), the seeds are not properly after-ripened until the twelfth week. The longer the period of stratification, however, the greater chance there is of fungal contamination. Hence, by treating seeds that had been stratified for 1 to 12 weeks, it was possible to determine the effect of the fungicides in general on germination and preservation of partially after-ripened as well as on fully after-ripened seeds.

After planting the seeds were observed at weekly intervals as to the effectiveness of treatments on initial germination, and so as to secure data on the sound, non-germinating seeds and on the percentage of germination (Table I). It was noted that untreated lots germinated 2 to 4 days earlier than treated ones. It was recorded

TABLE I—PER CENT GERMINATION AND PER CENT SOUND LOVELL AND "NATURAL" PEACH SEED THAT HAD BEEN STRATIFIED FROM 1 TO 12 WEEKS, THEN TREATED BY DUSTING THE SEED WITH POWDER OF THE COMMERCIAL PREPARATIONS

Weeks Stratified	Commercial Preparations	Sound Seed (Per Cent)		Germination (Per Cent)	
		Treated	Untreated	Treated	Untreated
		Lovell Seed			
1	Semesan	16	12	0	0
2	Arasan	36	13	0	0
3	Spergon	58	10	0	8
4	Fermate	62	10	10	0
5	Ceresan	68	8	0	8
6	Semesan	20	18	0	16
7	Arasan	36	36	25	33
8	Spergon	60	22	50	20
9	Fermate	64	34	40	33
10	Ceresan	66	18	0	11
11	Semesan	26	26	0	25
12	Arasan	36	16	33	14
		"Natural" Seed			
1	Ceresan	82	16	0	0
2	Fermate	72	18	0	0
3	Spergon	74	16	0	10
4	Arasan	36	14	0	0
5	Semesan	25	15	0	0
6	Ceresan	80	24	0	23
7	Fermate	72	33	58	33
8	Spergon	74	28	54	20
9	Arasan	32	34	45	36
10	Semesan	32	34	0	30
11	Ceresan	78	30	0	33
12	Fermate	68	28	80	30

that with some treatments, non-germinating seeds were sound and preserved in good condition, whereas most of the untreated seeds which had not germinated were decayed and disintegrated. Spergon, Fermate, and Ceresan, especially, preserved the seed well, with Arasan and Semesan to a lesser degree. This indicates that both viable and non-viable seeds were protected in varying degrees against fungal attack.

The percentage of germination (Table I) is significantly greater after treatment with some fungicides than is the germination of untreated seed. The percentage of germination of seed treated with Fermate and Spergon compared favorably to that secured by the excised-embryo method (3), namely, Lovells, 40 to 50 per cent; and "Naturals", 80 to 90 per cent. Although these fungicides resulted in increased germination, others proved either ineffective or harmful. Semesan and Ceresan were toxic in the concentrations used in this experiment, while Arasan was found to be only slightly effective in improving the percentage of germination.

Experiment 2:—Since Fermate, Spergon, and Arasan were most effective in improving germination in the previous experiment, these fungicides were used again in this experiment. Two lots of Lovell (No. 1 and No. 2) and one lot of "Natural" seed were used. Two hundred and fifty seeds of each lot were stratified in sand at weekly intervals for 5 to 14 weeks, and then removed from the stratification medium and dusted prior to planting. Care was taken to remove the excess dust so that only a thin film remained over the entire seed. After treatment, the seeds were planted in flats and placed in the greenhouse at about 65 degrees F to germinate.

Table II presents data of the percentage of sound seed and percentage of germination of treated and untreated lots of Lovell and "Natural" seed. Lovell No. 1 was "poor" seed, testing only 30 per cent by the excised-embryo method; therefore, the germination of both treated and untreated seed is low. However, the seed were preserved well, as shown by the high percentage of sound seed produced with every treatment. Lovell No. 2 tested 40 to 50 per cent by the excised-embryo method. The per cent germination of this lot is decidedly higher after the treatments, especially following treatment with Fermate. The percentage of sound seed is also greater following treatments. The "Naturals" germinated 80 to 90 per cent as tested by the excised-embryo method. Again, the treatment produced a higher percentage of germination, and also, a higher percentage of sound seed.

Experiment 3:—The Lovell and Salwey varieties were used in this experiment, Lovell being treated with Fermate, and Salwey with Semesan. A total of 280 seeds were used with 20 in each lot, half of which were treated and half remaining untreated. Before being stratified in peat moss, the seeds were dusted with the fungicides by the same method as in previous experiments. After a stratification period of 8 to 14 weeks, the seeds were removed and planted in flats in the greenhouse. A striking difference between treated and untreated seed was noted upon removal from the stratification medium. The treated

TABLE II—PER CENT GERMINATION AND PER CENT SOUND PEACH SEED STRATIFIED IN SAND 5 TO 14 WEEKS PREVIOUS TO DUSTING WITH COMMERCIAL PREPARATIONS OF FERMATE, SPERGON, AND ARASAN

Weeks Stratified	Commercial Preparations	Sound Seed (Per Cent)		Germination (Per Cent)	
		Treated	Untreated	Treated	Untreated
		Lovell No. 1 Seed			
5	Fermate	61	32	0	8
6	Spergon	62	30	0	0
7	Arasan	58	34	8	16
8	Fermate	60	35	42	0
9	Spergon	56	28	0	0
10	Arasan	58	26	0	0
11	Fermate	48	29	0	0
12	Spergon	50	26	9	0
13	Arasan	42	24	16	0
14	Fermate	40	20	9	0
		Lovell No. 2 Seed			
5	Fermate	62	30	0	0
6	Spergon	58	34	7	0
7	Arasan	64	36	7	8
8	Fermate	60	27	38	25
9	Spergon	56	30	25	0
10	Arasan	48	32	9	9
11	Fermate	58	26	33	17
12	Spergon	46	28	17	27
13	Arasan	54	22	20	20
14	Fermate	48	28	34	25
		"Natural" Seed			
5	Fermate	82	34	25	8
6	Spergon	62	27	9	9
7	Arasan	80	62	70	50
8	Fermate	88	60	85	58
9	Spergon	92	82	90	80
10	Arasan	70	68	37	62
11	Fermate	72	26	25	25
12	Spergon	64	40	60	30
13	Arasan	60	54	50	50
14	Fermate	78	38	77	33

seeds were clean and separated easily from the peat moss, while the untreated seeds were moldy and rotting and had peat moss clinging to them.

Table III gives the germination results of treated and untreated

TABLE III—COMPARATIVE PER CENT GERMINATION OF TREATED AND UNTREATED LOVELL AND SALWEY PEACH SEED, TREATED BY DUSTING THE SEED BEFORE STRATIFICATION, THE LOVELL SEED WAS DUSTED WITH FERMATE, AND SALWEY WITH SEMESAN

Weeks Stratified	Lovell Treated With Fermate Germination (Per Cent)		Salway Treated With Semesan Germination (Per Cent)	
	Treated	Untreated	Treated	Untreated
8	70	40	50	50
9	50	30	90	40
10	40	0	60	40
11	10	20	100	50
12	30	0	100	20
13	50	0	100	60
14	50	40	100	50
Average germination	43	18	86	43

seed of both varieties. In both cases the germination of the treated lots is greatly increased, and compares favorably with the tests by the excised-embryo method, in which Salwey tested 90 to 100 per cent and Lovell 50 to 60 per cent. The average per cent germination of the treated Lovell and Salwey seed over the untreated lots is nearly tripled and doubled respectively.

Semesan, which gave indications of being toxic to germination in Experiment 1, improved the percentage germination of the Salwey variety in this experiment. This may be due in part to the greater resistance of that variety to toxic materials. The treated seeds germinated 100 per cent for the period of 11 to 14 weeks as compared with 45 per cent germination of the untreated seed for the same period. In the case of the Lovell seeds which were treated with Fermate, uniform germination was shown throughout the 8- to 14-week period, whereas the untreated fluctuated in germination from one week to the next.

Experiment 4:—For this experiment, partially after-ripened peach seed were secured from California. Some pits had already split and the seeds were germinating, with the hypocotyl extending about 10 mm. The remaining whole pits were cracked, and dormant seeds were kept separate from the germinating ones. From the two lots, 100 seeds were treated and 100 left untreated, making a total of 400 seeds used. Both germinating and non-germinating seeds were dusted with Fermate by the same method as in previous experiments, and all seed were then planted in flats and placed in the greenhouse to germinate.

A germination test based on both germinating and non-germinating seed showed 85 to 90 per cent germination. As Table IV indicates, the

TABLE IV—EFFECT OF TREATMENT WITH FERMATE ON LOVELL PEACH SEED WHICH HAD ALREADY BEGUN TO GERMINATE FOLLOWING AFTER-RIPENING, AS COMPARED WITH LOVELL PEACH SEED WHICH WAS STILL DORMANT AND REQUIRED FURTHER AFTER RIPENING

Variety	Fungicide	Germination (Per Cent)		Condition of Seed When Treated
		Treated	Untreated	
Lovell	Fermate	88	95	Germinating, hypocotyl 10 mm
Lovell.	Fermate	94	60	Non-Germinating or dormant

treated non-germinating (or dormant) seed germinated 94 per cent as compared to 60 per cent for the untreated seed. Thus, the treated dormant seed compare favorably with the germination test for the lot. It is also obvious that treatment of partially germinating seed, at the concentration used, results in a slightly reduced stand as compared with the untreated seed, the treated germinating 88 per cent and untreated 95 per cent. Fig. 1A shows the stand of peach seedlings that were grown from treated seed, and Fig. 1B shows the stand from untreated seed. The same number of seeds were planted in each flat.

Experiment 5:—Since much of the peach seed is stratified in late fall and planted in the spring, a certain amount of molding occurs during that period. Therefore, in this experiment, the whole pits were

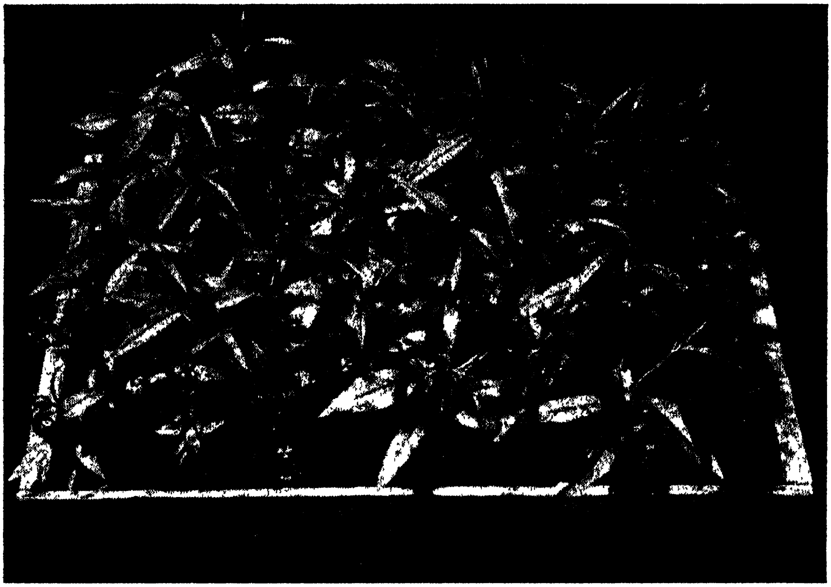

Fig. 1A. Peach seedlings grown from treated seed, showing 94 per cent germination

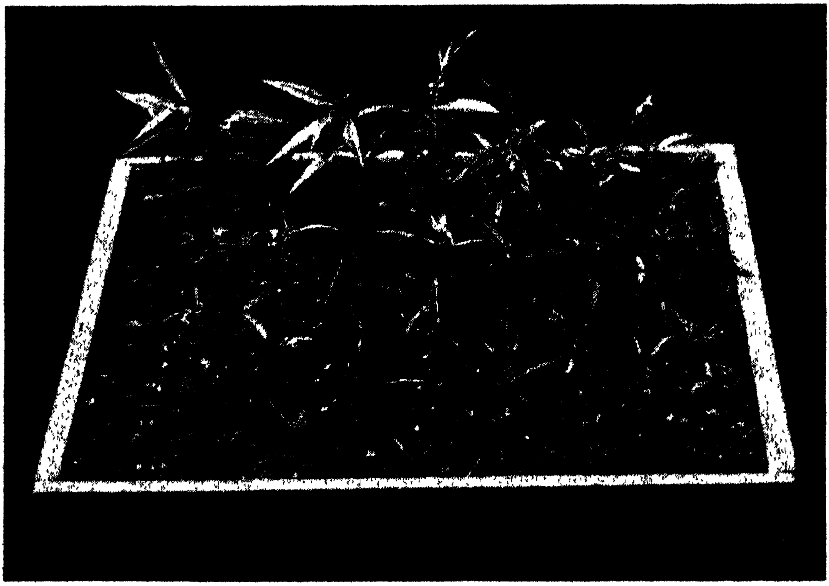

Fig. 1B. Peach seedlings grown from seeds which were not treated, showing 60 per cent germination.

treated and stratified in peat moss in an attempt to cut down loss due to decay. A total of 1700 pits were divided into lots of 100 and 125 pits. The presence of the stony pericarp or "pit" makes the method of dusting as used in previous experiments with seeds impractical for uniform and adequate coverage. Instead, aqueous solutions of the fungicide were used. Fermate and Zerlate were used in three concentrations, at the rate of 1, 2, and 3 pounds per 100 gallons of water. Some lots of pits were soaked in the solutions for 20 hours, while others were treated in the solutions in a 200 mm dessicator for 30 minutes (2) under partial vacuum. After these treatments the pits were packed in moist peat moss in clay pots and stored at 35 degrees F for 3 months. When the stratification period was ended most of the pits had split so that the seeds separated nicely. Pits that had not split were cracked by mechanical means. The seeds were then planted in flats and placed in the greenhouse to germinate.

The results are shown in Table V. Soaking the pits in the solution for 20 hours proved successful since germination of seeds from treated pits was 14 to 21 per cent greater than untreated lots. The concentrations of 2 and 3 pounds to 100 gallons of water proved superior to 1 pound to 100 gallons, when the pits were soaked for 20 hours, whereas all three concentrations seemed similarly effective under the vacuum treatments.

Contrasting the methods of treatment (soaking versus vacuum treatment), it appears that soaking the seed for 20 hours, especially in the higher solutions, is generally superior to vacuum treatment. In both cases of treatment, however, it is significant to note that germination of treated seeds equals the actual germination record as

TABLE V—Germination of Three Lots of Lovell Peach Seed, Some Treated by Soaking Whole Pits in Aqueous Solutions of Fermate and Zerlate, Others by Vacuum Intake of the Fungicidal Solution In Both Instances Treating was Done Prior to Stratification

Variety and Lot Number	Number of Pits	Material and Concentrations of Aqueous Solution	Germination (Per Cent)
Twenty Hours Soaking			
Lovell 9*	100	Water (control)	59
Lovell 9	100	1 pound Fermate per 100 gallons	73
Lovell 9	100	2 pounds Fermate per 100 gallons	79
Lovell 9	100	3 pounds Fermate per 100 gallons	80
Thirty Minutes Under Partial Vacuum Treatment			
Lovell 9*	100	Water (control)	63
Lovell 9	100	1 pound Fermate per 100 gallons	63
Lovell 9	100	2 pounds Fermate per 100 gallons	70
Lovell 9	100	3 pounds Fermate per 100 gallons	64
Lovell 10**	125	Water (control)	75
Lovell 10	125	1 pound Fermate per 100 gallons	85
Lovell 10	125	2 pounds Fermate per 100 gallons	71
Lovell 10	125	3 pounds Fermate per 100 gallons	77
Lovell 11†	100	Water (control)	74
Lovell 11	100	1 pound Zerlate per 100 gallons	77
Lovell 11	100	2 pounds Zerlate per 100 gallons	73
Lovell 11	100	3 pounds Zerlate per 100 galloms	72

*78 per cent germination by excised-embryo test.
**72 per cent germination by excised-embryo test.
†80 per cent germination by excised-embryo test.

tested by the excised-embryo method, whereas, the untreated seeds show a decrease of about 15 per cent.

Discussion

Since nurserymen often have difficulty in getting a good stand of peach seedlings for use as budding stock in the nursery, and since this is often true when apparently "good" seed is planted, some other factor or factors must be responsible for the poor stand. Although "poor" seed often causes uneven stand, "good" seed will do likewise when unfavorable conditions are present either during stratification or during germination, or both. These unfavorable conditions (wet and cold soils when the seeds are germinating in the spring, and too wet stratification media, or alternate wetting and drying of the media) are usually accompanied by a certain amount of molding and decaying of the seed which will reduce its ability to germinate. Therefore, improved germination and better stand in the nursery will result only if the unfavorable conditions are eliminated, or if some protection of the seed is supplied. Obviously, it would be difficult to eliminate unfavorable planting conditions in the spring, but those occurring during the stratification process could be reduced to a certain extent by proper care and the use of clean stratification media such as sand, peat moss, and sawdust. Additional protection may be secured by treatment of the seed with fungicides. It has been shown in the experiments in this paper that a significant degree of protection against mold and decay is obtained even under unfavorable conditions, accompanied by an increase in percentage of germination.

Since seed may be preserved to a certain extent by treatment, there is a possibility of holding seed for a period of time without appreciable loss of germinatability or decay. This could be significant commercially, for by removing and discarding the stony pericarp, and treating the seed before shipping, much of the bulk is disposed of which makes for easier handling, less storage space and less expense. It has also been shown (1) that seed alone, as well as the pit, can be stratified satisfactorily, although certain varieties and some older seed are particularly susceptible to fungal attack. Percentage germination is increased by treatment because of added and more definite protection against fungal attack. In addition, treatment seems somehow to result in improved germination.

On the basis of these laboratory results, it is to be hoped that field trials will work equally well, although actual data of field experiments are not yet completed and cannot be included here.

Summary

Peach seed and whole pits of Lovell, "Natural", and Salwey seed were treated in two ways: (a) the seeds were dusted with fungicide dusts, and (b) the whole pits were either soaked in an aqueous solution of the fungicide for 20 hours, or immersed in aqueous solutions of the fungicide under partial vacuum for 30 minutes. The whole pits were treated before stratification, whereas the seeds were treated either prior to or after stratification. All seeds were germinated in soil flats in the greenhouse at 65 degrees F. Six commercial fungicides (Arasan, Ceresan, Fermate, Semesan, Spergon, and Zerlate) were used. When used as dusting agents, the powder was used in the undiluted form, whereas, in soaking and vacuum treatments the fungicides were diluted at the rate of 1, 2, and 3 pounds to 100 gallons of water.

Of the six commercial preparations, Fermate and Spergon appeared to be most satisfactory at the concentrations used from the point of view of increased germination, less fungal contamination, and improved stand. The others, Arasan, Ceresan, Semesan, and Zerlate, responded to a less favorable degree. Semesan, though apparently toxic to Lovell seed, produced a favorable response to Salwey seed, which may be due to differences in the varieties. Since all the fungicides reduced the incidence of infection, it is possible that a greater range of concentration may give satisfactory responses.

In each of the five experiments there was an increased percentage of germination of the treated seed as compared with the untreated. Aside from increased germination, Experiments 1 and 2 showed also a favorable increase in the percentage of sound seed with each treatment (Tables I and II). In Experiment III, the average germination of treated Lovell seed was 43 per cent, and of untreated, 18 per cent; and with the Salwey variety, 86 per cent and 43 per cent respectively. Treatment of partially germinated seed resulted in decreased stand as compared with treatment of dormant seed (Table IV). The use of aqueous solutions of the fungicides in the treatment of pits produced a favorable increase in germination over the controls. The results of treatments of pits with aqueous solutions under partial vacuum, at the concentrations used, did not equal soaking. In both cases, the seed of treated pits compared favorably in percentage germination with the actual test by the excised-embryo method.

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Progress Report of Growth of Apple Trees on Malling Rootstocks

By W. W. Smith, *University of New Hampshire, Durham, N. H.*

Trees of several varieties on Malling stocks have been grown in New Hampshire for about 10 years. The accompanying table indicates the circumference of the trunks of trees in feet and is a fairly good indication of the size of the tree. In this experimental planting, apple trees on M I are outstanding in that they are larger and have a greater circumference than those on any other rootstock. The trees are more uniform in size and behavior on this stock.

Red Spy on M I planted in 1938 had a crop of apples in 1944, their sixth growing season, of nearly a peck of apples per tree. The Baldwin trees on M I also came into bearing in 1944. The variety Golden Delicious has done exceptionally well on M IV. Although these trees are not quite so large as those on M V, they are a little larger than those on M II; all Golden Delicious trees on these three rootstocks have borne two heavy crops, one in 1942 and in 1943, and a light crop in 1944. Golden Delicious trees on M XVI grew very vigorously, but Starking trees on M XVI grew very slowly; in fact, Starking on M XVI are smaller than Starking on any other of the Malling rootstocks in this experiment.

Macoun has made a very nice tree on either M IV or V, although the trees are a little larger on M V and seem to be a little better anchored. We have about 70 McIntosh trees on M IV in another planting which is younger and this combination has not been satisfactory on the poorer soil at certain locations in the orchard. However, on the better soil parts of the orchard, M IV has made good McIntosh trees. None of these trees have been staked or supported and only one has broken off at the union by wind. However, several of them are a little wobbly but stand upright and seem to be holding their own.

TABLE I—Circumference in Feet of Apple Tree Trunks 18 Inches from the Ground Level. Trees in Sod Mulch at Gilford, N. H.

Variety	Age Years	M I		M III		M IV		M V		M X		M XVI	
		No. Trees	Cir.	No. Trees	Cir.	No. Trees	Cir.	No. Trees	Cir.	No. Trees	Cir.	No. Trees	Cir.
Golden Delicious. . . .	9	—	—	5	0.71	18	0.73	5	0.82	—	—	5	0.89
Starking	9	7	0.85	—	—	2	0.58	3	0.47	—	—	4	0.42
Baldwin. . . .	8	9	0.93	—	—	—	—	5	0.81	2	0.64	—	—
Red Spy . .	8	10	0.73	4	0.92	—	—	1	0.89	—	—	—	—
Macoun.	9	—	—	—	—	12	0.58	5	0.68	—	—	—	—
Milton . .	9	—	—	—	—	5	0.56	—	—	—	—	—	—
McIntosh.	8	8	0.63	—	—	—	—	—	—	—	—	—	—
R. I. Greening	8	—	—	—	—	1	0.88	1	1.16	—	—	—	—

Orchard Performance of Peach Variety Seedlings as Rootstocks for Peaches

By LEON HAVIS and P. C. MARTH, *U. S. Department of Agriculture, Beltsville, Md.*, and F. E. GARDNER, *U. S. Department of Agriculture, Orlando, Fla.*

THE Carolina or Tennessee "Natural" peach seedling has been a fairly satisfactory peach rootstock for many years. Nurserymen found "Natural" seed easy to germinate and the seedlings were uniformly vigorous in the nursery; furthermore, peach varieties, when budded on them, were in general satisfactory in growth and productiveness in the orchard. Recently, however, "Natural" seed has become increasingly difficult to obtain. Many of the parent seedling trees have been replaced by named varieties, so that probably in a few more years there will be but few "Natural" seed-producing trees remaining where they were once numerous in such States as North Carolina, Tennessee, and Alabama. Seeds of an assortment of varieties are at present available to nurserymen. These seeds vary considerably in size and shape and are not always dependable in germination in the nursery. Several years ago it became evident that some source of seed for peach stock other than the "Carolina Natural" would be necessary, and little information was available on the relative merits of different peach varieties as rootstocks.

In the summer and fall of 1936 the stones of a large number of peach varieties were collected from the Plant Industry Station variety orchard and elsewhere and during November were planted in the nursery at Beltsville, Maryland. In the summer of 1937 the seedlings were budded to the Halehaven and Elberta varieties. The Elberta was budded on seedlings of 32 different peach varieties and the Halehaven on seedlings of 57 varieties. One-year trees of both Halehaven and Elberta were set out on November 30, 1938, in separate orchards near Salisbury, on the Eastern Shore of Maryland. Five trees on a given stock planted along a row constituted a plot. These plots were randomized in the Halehaven orchard planting. In the Elberta orchard the plots were also randomized for all varieties except "Commercial"; here a "Commercial" row was located every fifth row in the orchard. The number of plot replicates was variable, depending on the number of available trees and is stated in the tabulation.

The soil in both rootstock-test orchards is a Norfolk loamy sand. The orchards have been given uniformly good care and the trees have made vigorous growth. The fruit crop was largely destroyed by frosts, in both 1942 and 1943.

Trunk circumference was used as a measure of the relative growth of the trees on the different rootstocks. In order to determine the relative increase in trunk growth throughout these tests, circumference measurements obtained in November 1938 were compared with those obtained in November 1943. This was done by calculating the increase in trunk cross-sectional area for the 5-year period. Thus the increase in trunk area in square cm was obtained for each tree in the test.

Then the mean cross-sectional area increase for each plot of 5 trees was used as a unit or replicate in further analysis of the data.

HALEHAVEN ON DIFFERENT ROOTSTOCKS

In the Halehaven rootstock test block the number of replications of each rootstock varied from 2 to 14 with the 55 rootstock varieties compared in this report. Two additional rootstock varieties were planted, but since there was only one plot of each, the results are of questionable value. The mean increases in trunk size per tree for each of the 55 rootstock varieties were determined (Table I) and these were compared by use of the analysis of variance. A summary of the analysis of variance calculation is as follows:

TABLE I—MEAN INCREASE IN TRUNK SIZE PER TREE OF HALEHAVEN ON DIFFERENT ROOTSTOCKS

Rootstock	No. of Replications	Trunk Growth Increase in Cm^2 Per Tree	Rootstock	No. of Replications	Trunk Growth Increase in Cm^2 Per Tree
Admiral Dewey	2	159.1	Krummel	5	151.1
Admiral Dewey x			Late Crawford	4	140.3
St. John	4	139.4	Lemon Free	6	140.4
Alton	6	139.7	Libbee	3	148.0
Babcock	3	140.0	Linworth	2	155.1
Banner	8	145.3	Lukens	2	161.0
Barnard	3	134.9	Mao Tao	6	152.4
Belle	2	110.1	Marquette	3	133.1
Carman	3	134.0	Martha Fern	3	134.5
"Carolina Natural"	14	148.0	Mountain Rose	9	144.3
Champion	5	144.1	Muir	2	173.3
Chili	5	138.4	Newcomb	2	143.1
"Commercial"*	4	166.8	New Prolific	3	155.1
Early Crawford	4	133 5	Oldmixon Free	3	147.8
Elberta	4	147.8	Phillips (Calif.)	3	143.4
Engle	4	132.3	Phillips (Md.)	4	152.8
Eureka	3	133.2	Paloro	4	168.5
George IV	3	125.0	Ray	3	166.2
Giant Snowball	3	156.1	Rochester	3	155.9
Globe	2	124.5	St. Claire	4	162.9
Gold Drop	3	137 8	Salberta	4	159.1
Halberta	3	145.5	Shippers Late Red	3	162.1
Halehaven	2	126.1	Sims	3	165.8
Halford No. 1	3	137.5	South Haven	3	155.7
Illinois	6	155.5	Stump	4	151.6
Johnson	4	151.3	Summer Heath	3	146.1
July Elberta	2	154.1	Sun Glo	3	145.3
Kalamazoo	8	154.4	Veteran	4	140.0

*Probably "Naturals" from Alabama

Source of Variation	Degrees of Freedom	Mean Squares	F
Total	214	——	—
Rootstock	54	530.66	*
Within rootstock	160	568.63	—

*Mean square for error is greater than that for rootstock, therefore differences between rootstock means are not significant.

Since the analysis of variance failed to show that there were significant differences between rootstocks in the Halehaven orchard, it was decided to determine whether some of the differences in growth were due to position in the orchard planting. For this analysis the planting was divided arbitrarily into 8 parts or blocks and the mean trunk-area increase for each block was used as a unit in the analysis of variance. A summary is as follows:

Source of Variance	Degrees of Freedom	Mean Squares	F
Total	214	—	—
Block	7	4269.97	9.84**
Within blocks	207	434.05	—

**Significant at 99:1 level

This analysis of variance indicates that there were highly significant differences in growth due to block or location of the trees in the planting. Therefore, since no significant differences were shown between rootstock varieties, at least a part of the variability among them was probably due to their location. It should be emphasized that each of these arbitrary block locations did not include the same number of plots of each rootstock; also that the number of plots of each rootstock varies considerably, and only chance determined whether a given variety was located in any block position.

The fact that no statistically significant differences between the different rootstocks was shown by the analysis of variance does not necessarily mean that all stocks responded alike. It does show mathematically, however, that the variation within varieties, due to location and other factors, was relatively greater than the variation due to differences between varieties.

ELBERTA ON DIFFERENT ROOTSTOCKS

The Elberta rootstock orchard was composed of 32 variety rootstocks. Each plot was made up of five trees. The number of replications of each rootstock varied from 2 to 10 in this orchard. The mean increase per tree in square centimeters from 1938 to 1943 was calculated (Table II). In order to determine the significance of the mean

TABLE II—MEAN INCREASE IN TRUNK CIRCUMFERENCE PER TREE OF ELBERTA ON DIFFERENT ROOTSTOCKS

Rootstock	Mean (Sq Cm)	Rootstock	Mean (Sq Cm)
Muir	155.5	Champion	123.8
Halberta	147.3	Ray	123.1
Mao Tao	146.1	Marquette	122.6
"Commercial"*	139.9	Banner	122.4
Babcock	136.5	"Carolina Natural"	122.4
Martha Fern	135.6	Kalamazoo	122.3
Stump	135.1	Lemon Free	122.3
Krummel	135.0	Lukens	121.4
St. Claire	132.9	Phillips	118.5
Alton	132.0	Chili	118.1
Libbee	131.3	Illinois	115.5
Elberta x Newcomb**	130.5	Admiral Dewey	115.2
Admiral Dewey x St. John**	129.8	Mountain Rose	114.2
Johnson	129.0	New Prolific	112.7
Gold Drop	128.9	Veteran	112.6
Salwey x Walton**	128.0	Engle	109.5

*Probably "Naturals" from Alabama
**Promising unnamed seedlings

differences between stocks, the data for all varieties except "Commercial" were analyzed by the method of analysis of variance. The "Commercial" was not included in this analysis, since every fifth row was planted to this variety rather than a random distribution of it. The significance of the different means in comparison with "Commercial" was determined by use of "Student's" method. A summary of the analysis of variance for all stock varieties except "Commercial" is given:

Source of Variance	Degrees of Freedom	Mean Squares	F
Total	117	—	—
Rootstock	30	528.2	1.92**
Within rootstocks	87	274.9	—

**Significant at 99:1 level

Thus evidently there is a highly significant difference between the means of certain of the rootstocks (Table II). The difference required for significance between any two of these means of treatments is quite variable, depending on the number of plots or replications in each. These varied from 2 to 10 with the varieties used. It should be emphasized that the means given (Table II) may be misleading unless it is clear that the differences required for significance are based on the number of replicates. For example, the mean circumference of Halberta is greater than Mao Tao, yet, since there are only two replicates of Halberta in contrast to four of Mao Tao, a greater difference is required for significance when Halberta is compared with any other variety. Based on these differences required for significance, the following differences were found at the 99:1 level:

Mao Tao > Engle, Illinois, Mountain Rose, New Prolific, Veteran
Muir > Chile, Engle, Illinois, Mountain Rose, New Prolific, Veteran
Halberta > Engle

In order to determine the relative vigor of the "Commercial" stock and the other varieties used in the Elberta orchard, "Student's" method of analysis was employed. Since a "Commercial" row occurred every fifth row, no stock variety tree was farther than two rows from a "Commercial" or control tree. By pairing individual trees of "Commercial" and of each other stock variety, it was found that no variety stock resulted in more vigorous trees at odds of 99: 1. Based on these odds for significance, the following varieties gave Elberta trees of smaller trunk circumference than "Commercial":

Admiral Dewey x St. John
Banner
Champion
Engle
Gold Drop
Illinois
Kalamazoo
Lemon Free
Mountain Rose
Veteran

The other stock varieties used in this test showed no significant difference from "Commercial" in increase of trunk circumference when compared by this method.

On the basis of these two analyses it is evident that the rootstock varieties Mao Tao, Muir, Halberta, and "Commercial" resulted in greater increase in trunk area than certain other varieties. These four "superior" stocks showed no significant differences among themselves and none in comparison with many of the other varieties. Therefore, as a result of this test, it may be concluded that only a few varieties proved more vigorous than certain others, and that a great many of them showed no significant difference at the 99:1 level for significance.

In California, Day (1) found no appreciable differences after 3 years between the sizes of either Muir or J. H. Hale trees that were budded on Muir, Elberta, Salwey, and Lovell seedlings. Phillips Cling on the same four stocks showed no significant differences in growth or production after 10 years in the orchard.

DISCUSSION AND CONCLUSIONS

An analysis of the growth in trunk circumference of Elberta and Halehaven peach trees on a large number of varieties used as rootstocks indicated that there were but few significant differences in tree growth on the various rootstocks. These differences were noted only with the Elberta variety, probably due to the relatively less variability within the rootstock plots because of greater soil uniformity in this test orchard. Although there were definite differences in favor of certain rootstocks, it should be emphasized that there are other factors, such as availability of seed, percentage of germination, and ease of budding to be considered in choosing a source of peach seed.

Considerable difference has been reported (2) among peach varieties in the relative seed germination and growth of the seedlings in the nursery. There seems to be little or no relationship, however, between the vigor of the seedling in the nursery and the vigor of the tree budded on the seedling. For example, Muir was given a nursery rating of "poor" (2), whereas the Elbertas budded on Muir were of outstanding vigor (Table II). Considerable difference was found among the seedlings of peach varieties in their tolerance to "wet feet" (4). This factor is of considerable importance in certain soils, and in such cases there might have been striking growth differences between the varieties used as rootstocks. Under the soil conditions of this test, however, there seemed to be no relationship between the reported relative tolerance and the growth of the trees on these rootstocks. Although, as has been pointed out previously, the "Commercials" or "Naturals" are vigorous understocks for peaches, they are very susceptible to nematode rootknot (3). Even where nematodes are not serious, their use is limited, as previously mentioned, because of the scarcity of parent trees.

These results, based on 5 years of orchard testing, indicate that seeds of many peach varieties may be used as a source of seedling rootstocks for peaches insofar as vigor of trees in the orchard is concerned. A relatively few, however, such as Engle, Illinois, and New Prolific, evidently should be avoided if others are available. The Muir and Mao Tao may well be used with confidence insofar as vigor of budded trees is concerned. In choosing a variety for rootstock purposes, the germination percentage and seedling rating (based on vigor, uniformity, and character of growth), as previously found (2), should be considered. Based on seedling rating and orchard performance, the Lemon Free, Banner, Champion, Gold-Drop, and Admiral Dewey are among the most promising varieties. There are no statistically significant differences between these 5 varieties in the orchard, and no variety (including "Commercial") was significantly higher than these in budded-tree vigor.

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Characteristics of the Progeny Obtained from Utilizing Standard Commercial Varieties in Apple Breeding

By FREEMAN S. HOWLETT and J. H. GOURLEY, *Ohio Agricultural Experiment Station, Wooster, O.*

THE dependable bearing habits of Rome Beauty, which, unfortunately are combined with less desirable dessert quality, have stimulated efforts to obtain an apple variety as late in blooming and harvesting but of improved quality. To this end, primarily, the Ohio Agricultural Experiment Station has designed and carried out its apple breeding program, although certain crosses have also been made in the hope of obtaining new varieties of superior quality, regardless of the late-blooming characteristic.

This paper is the second in a series describing the progeny obtained by crossing certain standard commercial varieties. The first of these reports (1) published the period of blooming, certain fruit characteristics and season of harvesting as found in seedlings having Rome Beauty, Gallia Beauty and Golden Delicious parentage. This paper deals with similar characteristics to be found in seedlings whose parentage is Delicious, Rome Beauty, Gallia Beauty, Jonathan, McIntosh, Wealthy and Northern Spy, as well as certain of their mutations. It should be clearly understood that the work was not designed as a study of inheritance in the apple but as a practical means of obtaining seedlings which fulfilled the specifications above mentioned.

Descriptions of these fruits were compiled at Wooster during the period 1929 to 1945, under the headings: size, color and dessert quality, season of bloom and date of harvesting. Resultant tree characteristics will be presented in a later report, together with results obtained from backcrossing certain seedlings of these groups with their parents and crosses between seedlings of the same parentage. With one exception, data are presented here, only in case as many as 10 seedlings were obtained from the cross, the exception being the eight seedlings obtained from selfing Jonathan.

The fruits, with very few exceptions were described by the writers. The data on bloom were taken entirely by one individual, the same being true of the harvesting date. Where seedlings were harvested at different dates in different years, the dates were averaged for a final compilation of the data. With a great majority of the crosses the data represent the findings of only one season, since unless a seedling possessed some particularly desirable characteristic, such as value in further breeding, or unless it merited limited trial, it was removed the winter after its fruit was examined since it was uneconomical to maintain totally undesirable seedlings in the plantation.

It should be pointed out that the seedlings were planted eight feet apart in rows 16 feet wide and therefore developed quite satisfactorily. Spraying, and all operations other than pruning and thinning, were carried out as with a commercial plantation.

PRESENTATION OF RESULTS

In the following tables the crosses are arranged with reference to the principal commercial varieties which served as parents, an arrangement which obviously results in some repetition of the data, but which is more convenient in comparing results within the variety. Figs. 1 to 5 present in descending scale the 10 leading varietal combinations with respect to each of the characteristics herein considered.

Fruit Size:—Table I presents a summary of the data relative to fruit size. As indicated by Fig. 1, McIntosh x Gallia Beauty was superior in producing the greatest percentage of seedlings with fruits "Above Medium" and "Large". In this respect the cross seemed to be superior to its reciprocal. Other seedlings resulting from Gallia Beauty as the egg cell parent, such as Gallia Beauty x Red Spy, or Gallia Beauty x Starking, produced in general only "Small" to "Medium" fruits. McIntosh x Delicious also gave a considerable proportion of fruits of unsatisfactory size, yet Northern Spy x Delicious and Delicious x Golden Delicious produced a relatively high percentage of fruits "Above Medium" and "Large". Delicious x Gallia Beauty and Northern Spy x Rome Beauty resulted, however, in fruits of only moderate size, which is not surprising in view of the data presented previously by Hartman and Howlett (1) as a result of selfing Gallia

TABLE I—DISTRIBUTION OF SEEDLING PROGENY OF APPLE VARIETIES ON BASIS OF FRUIT SIZE

Parentage	Number of Seedlings	Per Cent of Large Seedlings	Per Cent of Seedlings Above Medium	Per Cent of Medium Seedlings	Per Cent of Seedlings Below Medium	Per Cent of Small Seedlings
			Delicious			
Delicious × Gallia Beauty	116	6.0	7.8	55.2	13.8	17.2
Gallia Beauty × Starking	52	9.6	—	46.2	9.6	34.0
Delicious × Golden Delicious	24	8.3	16.7	58.3	4.2	12.5
Jonathan × Delicious	34	2.9	—	50.0	8.8	38.2
McIntosh × Delicious	12	8.3	—	50.0	16.7	25.0
Northern Spy × Delicious	43	14.0	11.6	48.8	9.3	16.3
			Gallia Beauty and Rome Beauty			
Gallia Beauty × Jonathan	21	—	9.5	66.7	4.8	19.0
Gallia Beauty × McIntosh	64	7.8	14.1	53.1	10.9	14.1
McIntosh × Gallia Beauty	14	28.6	7.1	57.1	—	7.1
Gallia Beauty × Starking	52	9.6	—	46.2	9.6	34.6
Delicious × Gallia Beauty	116	6.0	7.8	55.2	13.8	17.2
Gallia Beauty × Red Spy	51	7.8	7.8	49.0	17.6	17.6
Northern Spy × Rome Beauty	27	7.4	11.1	63.0	3.7	14.8
			Jonathan			
Jonathan selfed	8	—	—	50.0	12.5	37.5
Jonathan × Delicious	34	2.9	—	50.0	8.8	38.2
Jonathan × Northern Spy	32	3.1	15.6	46.9	15.6	18.8
Gallia Beauty × Jonathan	21	—	9.5	66.7	4.8	19.0
			McIntosh			
McIntosh × Delicious	12	8.3	—	50.0	16.7	25.0
McIntosh × Gallia Beauty	14	28.6	7.1	57.1	—	7.1
Gallia Beauty × McIntosh	61	7.8	14.1	53.1	10.9	14.1
			Northern Spy and Red Spy			
Northern Spy × Delicious	43	14.0	11.6	48.8	9.3	16.3
Northern Spy × Rome Beauty	27	7.4	11.1	63.0	3.7	14.8
Gallia Beauty × Red Spy	51	7.8	7.8	49.0	17.6	17.6
Northern Spy × Wealthy	61	6.6	4.9	68.9	14.8	4.9
Jonathan × Northern Spy	32	3.1	15.6	46.9	15.6	18.8

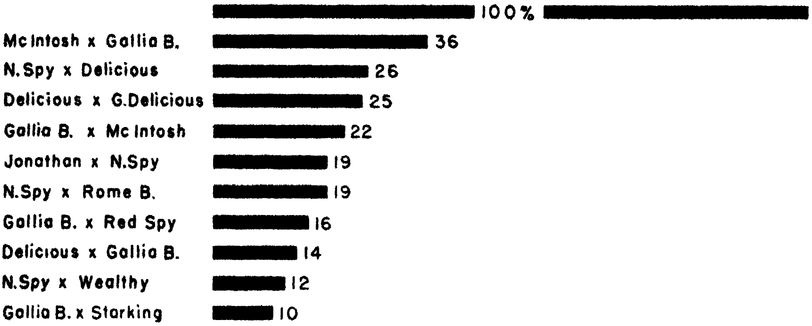

FIG. 1. Percentage of seedlings with fruits above medium or large.

Beauty and Rome Beauty. These two varieties selfed produced a very large percentage of seedlings whose fruits were "Medium" or less in size.

Jonathan x Delicious was distinguished for producing seedlings with fruits so small as to emerge almost at the bottom of the list, a fact which is not surprising in view of the generally small size of fruits obtained from selfing Jonathan. The definitely inferior results of crossing Gallia Beauty and Jonathan were not surprising either in view of the behavior of Gallia Beauty when selfed (1) and in view of results obtained from crossing with Red Spy, Delicious and Starking.

Fruit Color:—Table II presents the distribution of the progeny on the basis of fruit color (over-color). The seedlings obtained from selfing Jonathan and from crossing Gallia Beauty with Starking excelled by a wide margin all other combinations with respect to the percentage completely colored. The progeny of Jonathan selfed, Northern Spy x Wealthy and Jonathan x Delicious involved no seedlings with fruits lacking over-color while the cross Delicious x Golden Delicious had the greatest percentage of seedlings without any over-color whatsoever. The seedlings obtained by crossing Northern Spy with Delicious, McIntosh with Gallia Beauty and McIntosh with Delicious were inferior in fruit coloration to the other combinations.

Fig. 2 indicates graphically in descending order the rank of the 10 combinations showing fruits with the surface half colored or better. The progeny of Jonathan selfed, Jonathan x Delicious and Gallia Beauty x Jonathan excelled on this basis. Gallia Beauty x Starking seedlings were slightly superior to Delicious x Gallia Beauty in this respect while Gallia Beauty x Red Spy progeny were superior to Northern Spy x Rome Beauty. This latter combination was definitely inferior to all but the seedlings from Delicious x Golden Delicious with respect to fruits with less than 50 per cent over-color.

Fruit Quality:—Table III presents the distribution of progeny on the basis of dessert quality of the fruit. Fig. 3 shows graphically the rank in descending order of the combinations which gave the greatest proportion of fruits "Medium good" and "Above". Especially to be noted is the superiority of the seedlings involving Northern Spy as one

TABLE II—Distribution of Seedling Progeny of Apple Varieties on Basis of Fruit Color

Parentage	Number of Seedlings	Per Cent of Complete or Solid Color	50 Per Cent or More Colored	Less Than 50 Per Cent Colored	Blush or No Over Color
Delicious					
Delicious × Gallia Beauty	116	19.8	50.0	10.3	19.8
Gallia Beauty × Starking	52	42.3	34.6	11.5	11.5
Delicious × Golden Delicious	24	8.3	33.3	20.8	41.7
Jonathan × Delicious	34	8.8	88.2	2.9	—
McIntosh × Delicious	12	—	59.3	8.3	33.3
Northern Spy × Delicious	44	—	61.4	2.3	36.4
Gallia Beauty and Rome Beauty					
Gallia Beauty × Jonathan	21	14.3	76.2	4.8	4.8
Gallia Beauty × McIntosh	64	9.4	59.4	7.8	23.4
McIntosh × Gallia Beauty	14	—	64.3	—	35.7
Gallia Beauty × Starking	52	42.3	34.6	11.5	11.5
Delicious × Gallia Beauty	116	19.8	50.0	10.3	19.8
Gallia Beauty × Red Spy	51	13.7	56.9	5.9	23.5
Northern Spy × Rome Beauty	26	3.8	50.0	19.2	26.9
Jonathan					
Jonathan selfed	8	37.5	62.5	—	—
Jonathan × Delicious	34	8.8	88.2	2.9	—
Jonathan × Northern Spy	32	—	71.9	25.0	3.1
Gallia Beauty × Jonathan	21	14.3	76.2	4.8	4.8
McIntosh					
McIntosh × Delicious	12	—	58.3	8.3	33.3
McIntosh × Gallia Beauty	14	—	64.3	—	35.7
Gallia Beauty × McIntosh	64	9.4	59.4	7.8	23.4
Northern Spy and Red Spy					
Northern Spy × Delicious	44	—	61.4	2.3	36.4
Northern Spy × Rome Beauty	26	3.8	50.0	19.2	26.9
Gallia Beauty × Red Spy	51	13.7	56.9	5.9	23.5
Northern Spy × Wealthy	61	4.9	80.3	14.8	—
Jonathan × Northern Spy	32	—	71.9	25.0	3.1

parent. Even Northern Spy crossed with Rome Beauty ranked third in the number of such seedlings, and in this respect the data differ from those obtained by Wellington (4). The progeny from McIntosh, Delicious, Jonathan and Golden Delicious were quite satisfactory but appreciably inferior to the Northern Spy seedlings. McIntosh crossed with Gallia Beauty resulted in seedlings superior to those obtained

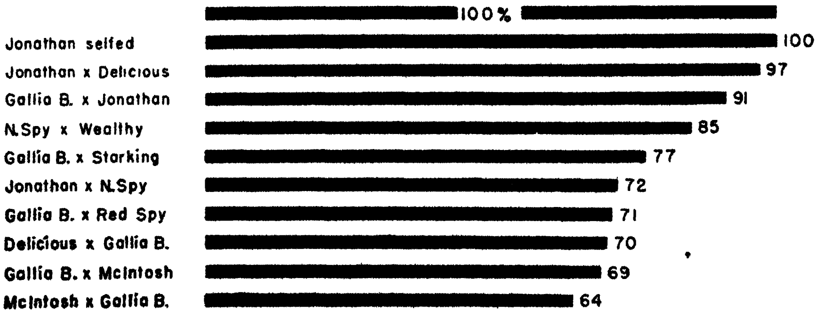

Fig. 2. Percentage of seedlings with fruits showing 50 per cent color or above.

TABLE III—DISTRIBUTION OF SEEDLING PROGENY OF APPLE VARIETIES ON BASIS OF FRUIT QUALITY

Parentage	Number of Seedlings	Per Cent Very Good	Per Cent Good	Per Cent Medium Good	Per Cent Fair	Per Cent Medium Fair	Per Cent Poor	Per Cent Very Poor
Delicious								
Delicious × Gallia Beauty..	116	—	1.7	1.7	42.2	0.9	50.0	3.4
Gallia Beauty × Starking ...	52	—	—	—	46.2	—	48.1	5.8
Delicious × Golden Delicious	24	—	16.7	8.3	33.3	4.2	29.2	8.3
Jonathan × Delicious.....	34	—	11.8	8.8	47.1	8.8	23.5	—
McIntosh × Delicious	12	—	8.3	16.7	58.3	—	8.3	8.3
Northern Spy × Delicious...	44	—	18.2	15.9	34.1	6.8	22.7	2.3
Gallia Beauty and Rome Beauty								
Gallia Beauty × Jonathan ..	21	—	—	—	61.9	14.3	19.0	4.8
Gallia Beauty × McIntosh	62	—	0.5	4.8	48.4	1.6	35.5	3.2
McIntosh × Gallia Beauty..	14	—	7.1	7.1	50.0	14.3	14.3	7.1
Gallia Beauty × Starking....	52	—	—	—	46.2	—	48.1	5.8
Delicious × Gallia Beauty.	116	—	1.7	1.7	42.2	0.9	50.0	3.4
Gallia Beauty × Red Spy .	51	—	—	5.9	33.3	9.8	43.1	7.8
Northern Spy × Rome Beauty	27	3.7	3.7	25.9	44.4	—	22.2	—
Jonathan								
Jonathan selfed	8	—	12.5	12.5	50.0	12.5	12.5	—
Jonathan × Delicious	34	—	11.8	8.8	47.1	8.8	23.5	—
Jonathan × Northern Spy	32	—	31.3	15.6	34.4	—	15.6	3.1
Gallia Beauty × Jonathan .	21	—	—	—	61.9	14.3	19.0	4.8
McIntosh								
McIntosh × Delicious	12	—	8.3	16.7	58.3	—	8.3	8.3
McIntosh × Gallia Beauty	14	—	7.1	7.1	50.0	14.3	14.3	7.1
Gallia Beauty × McIntosh	62	—	6.5	4.8	48.4	1.6	35.5	3.2
Northern Spy and Red Spy								
Northern Spy × Delicious .	44	—	18.2	15.9	34.1	6.8	22.7	2.3
Northern Spy × Rome Beauty..........	27	3.7	3.7	25.9	44.4	—	22.2	—
Gallia Beauty × Red Spy.	51	—	—	5.9	33.3	9.8	43.1	7.8
Northern Spy × Wealthy...	61	—	6.6	19.7	39.3	9.8	23.0	1.6
Jonathan × Northern Spy	32	—	31.3	15.6	34.4	—	15.6	3.1

from any other combination involving Gallia Beauty, a parent which was definitely inferior. The outstanding inferiority of the combination Gallia Beauty x Red Spy to Northern Spy x Rome Beauty is to be noted. Delicious and Starking crossed with Gallia Beauty were particularly poor combinations from the fruit quality viewpoint.

Blooming Season:—Table IV presents the data for the seedling progeny in relation to blooming season. The difference in days between the first day of full bloom of each seedling and each of its parents was determined and from these data the percentage of the progeny included in each time interval was calculated. The lateness of bloom of the seedlings relative to their parents is to be particularly noted. The progeny from Jonathan self-pollinated, although comprised of only eight seedlings, included five blooming later than Jonathan. Even the seedlings obtained from crossing Jonathan with Delicious were somewhat later than either parent. The combination Northern Spy x Rome Beauty gave the highest percentage of late blooming seedlings. Fifty-six per cent came into full bloom five or more days after Rome Beauty.

TABLE IV—Distribution of Seedling Progeny of Apple Varieties on Basis of Date of Full Bloom

Percentage of Seedlings	Parent Involved	Percentage of Seedlings With Bloom as Indicated for Parent Given in Second Column																		
		Days Before						Days After												
		5	4	3	2	1	0	1	2	3	4	5	6	7	8	9	10	11	12	13
								Delicious												
Delicious ×Gallia Beauty	Delicious	0.9	—	—	0.9	3.7	15.6	24.8	25.7	12.8	3.7	1.8	3.7	1.8	0.9	0.9	1.8	0.9	—	—
	Gallia Beauty	0.9	—	—	0.9	3.7	28.4	21.6	9.8	2.9	3.9	1.0	1.0	2.0	1.0	—	—	—	—	—
Gallia Beauty ×Starking	Gallia Beauty	—	—	—	11.8	23.5	8.8	38.2	8.8	8.8	—	—	—	—	—	—	—	—	—	—
	Starking	—	—	—	—	11.8	17.6	8.8	38.2	8.8	14.7	—	—	—	—	—	—	—	—	—
Delicious ×Golden Delicious	Delicious	—	—	—	—	5.3	26.3	21.1	15.8	10.5	10.5	5.3	—	5.3	—	—	—	—	—	—
	Gol. Delicious	—	—	—	—	10.0	30.0	20.0	10.0	15.0	10.0	5.0	—	—	—	—	—	—	—	—
Jonathan ×Delicious	Jonathan	—	—	—	—	—	—	16.7	27.8	30.6	—	5.6	16.7	2.8	—	—	—	—	—	—
	Delicious	—	—	—	—	—	—	13.9	25.0	33.3	2.8	5.6	16.7	2.8	—	—	—	—	—	—
McIntosh ×Delicious	McIntosh	—	—	—	—	—	—	25.0	—	16.7	41.7	16.7	—	—	—	—	—	—	—	—
	Delicious	—	—	—	—	—	25.0	—	33.3	41.7	—	—	—	—	—	—	—	—	—	—
Northern Spy ×Delicious	N. Spy	—	—	—	2.4	—	12.2	12.2	19.5	41.3	4.9	—	2.4	—	—	—	—	—	—	—
	Delicious	—	—	—	—	—	—	2.4	9.8	9.8	22.0	39.0	2.4	14.6	—	—	—	—	—	—
								Gallia Beauty and Rome Beauty												
Gallia Beauty ×Jonathan	Gallia Beauty	—	—	—	9.5	14.3	28.6	9.5	14.3	4.8	4.8	—	—	4.8	9.5	—	—	—	—	—
	Jonathan	—	—	—	—	—	14.3	9.5	9.5	19.0	14.3	4.8	14.3	—	4.8	—	4.8	—	4.8	—
Gallia Beauty ×McIntosh	Gallia Beauty	—	—	6.7	13.3	23.3	25.0	20.0	3.3	3.3	1.7	—	—	1.7	—	1.7	—	—	—	—
	McIntosh	—	—	—	—	—	—	6.7	25.0	25.0	28.3	6.7	6.7	5.0	—	—	—	1.7	—	1.7
McIntosh ×Gallia Beauty	McIntosh	—	—	—	—	—	—	14.3	14.3	14.3	7.1	21.4	21.4	7.1	—	—	—	—	—	—
	Gallia Beauty	—	7.1	14.3	21.4	7.1	21.4	7.1	7.1	14.3	—	—	—	—	—	—	—	—	—	—
Gallia Beauty ×Starking	Gallia Beauty	—	—	—	11.8	23.5	8.8	38.2	8.8	8.8	—	—	—	—	—	—	—	—	—	—
	Starking	—	—	—	—	11.8	17.6	8.8	38.2	8.8	14.7	—	—	—	—	—	—	—	—	—
Delicious ×Gallia Beauty	Delicious	0.9	—	—	0.9	3.7	15.6	24.8	25.7	12.8	3.7	1.8	3.7	1.8	0.9	0.9	1.8	0.9	—	—
	Gallia Beauty	0.9	—	—	0.9	3.7	28.4	21.6	9.8	2.9	3.9	1.0	1.0	2.0	1.0	—	—	—	—	—
Gallia Beauty ×Red Spy	Gallia Beauty	—	—	—	4.1	2.0	8.2	22.4	22.4	22.4	10.2	4.1	2.0	2.0	—	—	—	—	—	—
	Red Spy	—	—	—	—	2.0	2.0	20.4	18.4	30.6	16.3	8.2	2.0	—	—	—	—	—	—	—
Northern Spy ×Rome Beauty	N. Spy	—	—	—	—	4.0	—	4.0	16.0	12.0	20.0	24.0	16.0	4.0	—	—	—	—	—	—
	Rome Beauty	—	—	—	—	—	—	—	8.0	12.0	20.0	28.0	12.0	8.0	8.0	—	—	4.0	—	—

								Jonathan												
Jonathan Selfed	——	—	—	—	—	—	12.5	25.0	—	25.0	—	25.0	—	—	—	—	—	12.5	—	—
Jonathan ×Delicious	Jonathan	—	—	—	—	—	—	16.7	27.8	30.6	—	5.6	16.7	2.8	—	—	—	—	—	—
	Delicious	—	—	—	—	—	—	13.9	25.0	33.3	2.8	5.6	16.7	2.8	—	—	—	—	—	—
Jonathan ×Northern Spy	Jonathan	—	—	—	—	—	—	—	10.7	32.1	32.1	10.7	7.1	7.1	—	—	—	—	—	—
	N. Spy	—	—	—	—	—	10.0	16.7	36.7	20.0	13.3	3.3	—	—	—	—	—	—	—	—
Glalia Beauty ×Jonathan	Gallia	—	—	—	9.5	14.3	28.6	9.5	14.3	4.8	4.8	—	—	4.8	9.5	—	—	—	—	—
	Jonathan	—	—	—	—	—	14.3	9.5	9.5	19.0	14.3	4.8	14.3	—	4.8	—	4.8	—	4.8	—
								McIntosh												
McIntosh ×Delicious	McIntosh	—	—	—	—	—	—	25.0	—	16.7	41.7	16.7	—	—	—	—	—	—	—	—
	Delicious	—	—	—	—	—	25.0	—	33.3	41.7	—	—	—	—	—	—	—	—	—	—
McIntosh ×Gallia Beauty	McIntosh	—	—	—	—	—	—	14.3	14.3	14.3	7.1	21.4	21.4	7.1	—	—	—	—	—	—
	Gallia	—	7.1	14.3	21.4	7.1	21.4	7.1	7.1	14.3	—	—	—	—	—	—	—	—	—	—
Gallia Beauty ×McIntosh	Gallia Beauty	—	—	6.7	13.3	23.3	25.0	20.0	3.3	3.3	1.7	—	—	1.7	—	1.7	—	—	—	—
	McIntosh	—	—	—	—	—	—	6.7	25.0	25.0	28.3	6.7	6.7	5.0	—	—	—	1.7	—	1.7
								Northern Spy and Red Spy												
Northern Spy ×Delicious	N Spy	—	—	—	2.4	—	12.2	12.2	19.5	46.3	4.9	—	2.4	—	—	—	—	—	—	—
	Delicious	—	—	—	—	—	—	2.4	9.8	9.8	22.0	39.0	2.4	14.6	—	—	—	—	—	—
Northern Spy ×Rome Beauty	N Spy	—	—	—	—	4.0	—	4.0	16.0	12.0	20.0	24.0	16.0	4.0	—	—	—	—	—	—
	Rome	—	—	—	—	—	—	—	8.0	12.0	20.0	28.0	12.0	8.0	8.0	—	—	4.0	—	—
Gallia Beauty ×Red Spy	Gallia	—	—	—	4.1	2.0	8.2	22.4	22.4	22.4	10.2	4.1	2.0	2.0	—	—	—	—	—	—
	Red Spy	—	—	—	—	2.0	2.0	20.4	18.4	30.6	16.3	8.2	2.0	—	—	—	—	—	—	—
Northern Spy ×Wealthy	N. Spy	—	—	—	—	—	3.3	8.3	21.7	40.0	15.0	6.7	5.0	—	—	—	—	—	—	—
	Wealthy	—	—	—	—	—	—	—	1.7	1.7	6.7	6.7	30.0	30.0	15.0	5.0	3.3	—	—	—
Jonathan ×Northern Spy	Jonathan	—	—	—	—	—	—	—	10.7	32.1	32.1	10.7	7.1	7.1	—	—	—	—	—	—
	N. Spy	—	—	—	—	—	10.0	16.7	36.7	20.0	13.3	3.3	—	—	—	—	—	—	—	—

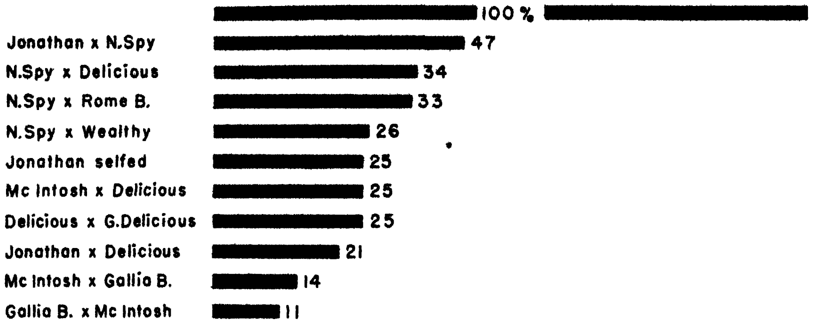

FIG. 3. Percentage of seedlings with fruits medium good or above in dessert quality.

Fig. 4 presents graphically the parents giving the latest bloom in relation to Rome Beauty, Gallia Beauty, and Northern Spy. Although these varieties have the same average date, May 10, for the beginning of full bloom, the data in Table IV indicate a slightly different time of coming into full bloom. This divergence results from the fact that the date of full bloom for each seedling was compared with that for each of its parents in the year the seedling bloomed and the three varieties did not always coincide in their date of beginning of full bloom. The progeny from Northern Spy as one parent were superior to those of all other combinations in lateness of bloom. In particular, it is interesting to note the late bloom of seedlings obtained from crossing Northern Spy with Wealthy. Furthermore, Northern Spy x Rome Beauty seedlings were later than those obtained from crossing Gallia Beauty with Red Spy, while Gallia Beauty x Starking progeny excelled those obtained from Delicious x Gallia Beauty in respect to late blooming. Gallia Beauty crossed with Starking, Jonathan, and with Delicious was superior to McIntosh and McIntosh x Delicious and Delicious x Golden Delicious seedlings were inferior to all other combinations in this respect.

Date of Harvest:—Table V presents the distribution of progeny on the basis of picking date of the seedling progeny. Fig. 5 shows graphically the percentage of seedlings with fruits harvested during the period from October 6 to November 9. Examination of the table shows that the combination Northern Spy x Wealthy produced the highest percentage of seedlings harvested during September. Especially interesting was the high percentage of progeny from the cross of Jonathan with Northern Spy which were harvested during the same period. The combination McIntosh x Gallia Beauty gave 49 per cent harvested during September to 36 per cent for its reciprocal.

Fig. V shows an interesting relationship in the rank of the various combinations with respect to the date of fruit harvest. The progeny from Northern Spy x Rome Beauty, Gallia Beauty x Red Spy and Delicious x Golden Delicious surpassed all other combinations in the percentage harvested from October 6 to November 9. Gallia Beauty crossed with Starking, Delicious with Gallia Beauty and Northern

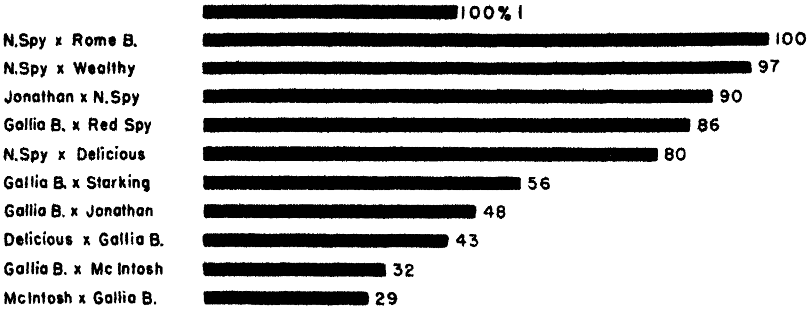

FIG. 4. Percentage of seedlings blooming 1 day or more after Rome Beauty, Gallia Beauty and Northern Spy.

Spy with Delicious gave a high proportion of late harvested seedlings while Jonathan crossed with Northern Spy and with Gallia Beauty resulted in such a small percentage of late harvested fruits that these two combinations did not rank within the first ten and were surpassed even by Jonathan x Delicious and Gallia Beauty x McIntosh in this respect. Gallia Beauty x McIntosh gave a higher percentage of late harvested seedlings than its reciprocal.

DISCUSSION OF THE DATA

The data show, as would be expected, that no one combination of parents produced progeny superior in all characteristics. Frequently the parents producing seedlings superior in one respect were definitely inferior in another. For example, Gallia Beauty x Red Spy was practically first in rank of those crosses producing the highest percentage of late-harvested fruits but was almost at the bottom of the list with respect to dessert quality. Another combination, Northern Spy x Wealthy, while quite satisfactory in fruit color, gave the highest percentage of September-harvested fruits. Even with respect to season of bloom and harvesting date there was considerable variation in the rank of the various combinations. For example, the Delicious x Golden Delicious combination showed a high percentage of late harvested fruits but the blooming season was generally mid-season. On the other hand the progeny of Jonathan x Northern Spy were quite late blooming but relatively early in time of harvest.

The data are also interesting in that they indicate definite differences between Gallia Beauty x McIntosh and its reciprocal with respect to certain characters. For example, Gallia Beauty x McIntosh produced a smaller number of large fruits but a greater number of late-harvested fruits than its reciprocal. The two combinations did not differ relative to color and quality of the fruits or season of bloom. The data also indicate differences between the combination Northern Spy x Rome Beauty and Gallia Beauty x Red Spy. Red Spy is presumably a bud mutation of Northern Spy while Gallia Beauty is a seedling of Rome Beauty which differs little except in over-color of

TABLE V—DISTRIBUTION OF SEEDLING PROGENY OF APPLE VARIETIES ON BASIS OF PICKING DATE

Parentage	No. of Seedlings	Sep 1–7	Sep 8–14	Sep 15–21	Sep 22–28	Sep29 Oct 5	Oct 6–12	Oct 13–19	Oct 20–26	Oct27 Nov2	Nov 3–9
Delicious											
Delicious × Gallia Beauty	113	—	—	0.9	8.8	12.4	15.9	17.7	23.0	7.1	14.2
Gallia Beauty × Starking	37	—	—	5.4	2.7	13.5	16.2	16.2	24.3	13.5	8.1
Delicious × Golden Delicious	22	—	9.1	—	4.5	4.5	18.2	13.6	13.6	31.8	4.5
Jonathan × Delicious	37	—	—	—	24.3	10.8	27.0	24.3	10.8	2.7	—
McIntosh × Delicious	12	—	—	8.3	16.7	16.7	33.3	—	16.7	—	8.3
Northern Spy × Delicious	43	—	—	—	7.0	16.3	20.9	14.0	41.9	—	—
Gallia Beauty and Rome Beauty											
Gallia Beauty × Jonathan	21	—	—	19.0	14.3	9.5	33.3	9.5	14.3	—	—
Gallia Beauty × McIntosh	61	—	—	9.8	9.8	16.4	36.1	16.4	9.8	1.6	—
McIntosh × Gallia Beauty	14	—	—	14.3	14.3	21.4	35.7	14.3	—	—	—
Gallia Beauty × Starking	37	—	—	5.4	2.7	13.5	16.2	16.2	24.3	13.5	8.1
Delicious × Gallia Beauty	113	—	—	0.9	8.8	12.4	15.9	17.7	23.0	7.1	14.2
Gallia Beauty × Red Spy	50	—	—	2.0	4.0	12.0	20.0	14.0	38.0	8.0	2.0
Northern Spy × Rome Beauty	27	—	—	—	—	14.8	11.1	48.1	22.2	3.7	—
Jonathan											
Jonathan Selfed	8	—	—	—	12.5	25.0	50.0	12.5	—	—	—
Jonathan × Delicious	37	—	—	—	24.3	10.8	27.0	24.3	10.8	2.7	—
Jonathan × Northern Spy	32	3.1	3.1	12.5	9.4	21.9	28.1	18.8	3.1	—	—
Gallia Beauty × Jonathan	21	—	—	19.0	14.3	9.5	33.3	9.5	14.3	—	—
McIntosh											
McIntosh × Delicious	12	—	—	8.3	16.7	16.7	33.3	—	16.7	—	8.3
McIntosh × Gallia Beauty	14	—	—	14.3	14.3	21.4	35.7	14.3	—	—	—
Gallia Beauty × McIntosh	61	—	—	9.8	9.8	16.4	36.1	16.4	9.8	1.6	—
Northern Spy and Red Spy											
Northern Spy × Delicious	43	—	—	—	7.0	16.3	20.9	14.0	41.9	—	—
Northern Spy × Rome Beauty	27	—	—	—	—	14.8	11.1	48.1	22.2	3.7	—
Gallia Beauty × Red Spy	50	—	—	2.0	4.0	12.0	20.0	14.0	38.0	8.0	2.0
Northern Spy × Wealthy	60	6.7	15.0	25.0	25.0	16.7	10.0	1.7	—	—	—
Jonathan × Northern Spy	32	3.1	3.1	12.5	9.4	21.9	28.1	18.8	3.1	—	—

the fruit as its fruit size, season of bloom and harvesting date are practically identical. Although the seedlings from these two combinations differed little in fruit size, Gallia Beauty x Red Spy was definitely superior in fruit color but inferior in quality. These differences are possibly expressions of the reported inferiority of Red Spy to Northern Spy in fruit quality and the superiority of Gallia Beauty to Rome

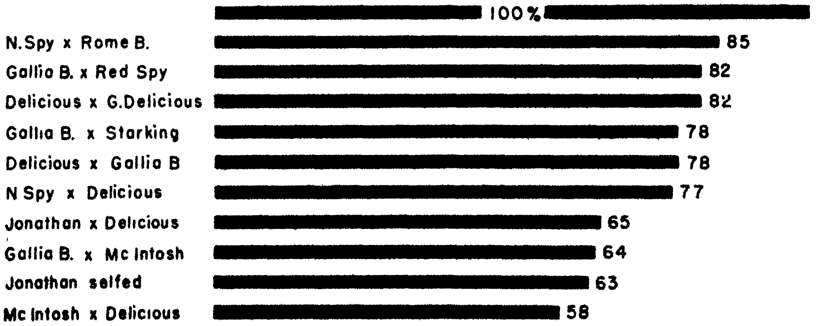

FIG. 5. Percentage of seedlings with fruits harvested October 6 to November 9.

Beauty in fruit color for in this connection Hartman and Howlett (1) presented data which indicated that Rome Beauty selfed gave a higher percentage of seedlings with poor color than Gallia Beauty. Northern Spy x Rome Beauty was superior in lateness of bloom but similar in harvest date.

Another interesting comparison is to be noted with Delicious x Gallia Beauty and Gallia Beauty x Starking. Probably the former was superior to the latter in size of fruit but the latter combination was definitely superior in color of fruit. Both were equally inferior in quality of fruit and equally late in time of harvest of the seedlings. In general, however, these combinations did not give much promise.

The progeny obtained from selfing Jonathan gave fruits which were either medium in size or smaller, a fact which was reflected in the small or medium-sized fruits produced when the variety was utilized in crosses with Gallia Beauty and Delicious. Wellington (4) found that the combination Rome Beauty x Jonathan produced generally small to medium-sized fruits. On the other hand, the fruits of all eight seedlings were better than half covered with red over-color. When utilized in crosses, the combinations involving Jonathan excelled all other (with one exception) in producing high over-color of the progeny. These data substantiate those presented by Wilcox and Angelo (5) and Lantz (2) indicating that Jonathan is superior to most other varieties in the number of cumulative genes favoring anthocyanin development. As found by Wilcox and Angelo (5) Wealthy was also superior in this respect. As opposed to these varieties, the generally inferior position of Gallia Beauty (except when crossed with Jonathan) is to be expected in view of the results obtained by Hartman and Howlett (1) in which both Gallia Beauty and Rome Beauty selfed gave a considerable proportion of seedlings with no over-color whatever.

If the five characters, size, color, and quality of fruit, blooming season and date of harvest are considered in ranking the various combinations, the cross Northern Spy x Rome Beauty was superior to the others. The seedlings resulting from this cross were followed in rank by the progeny from Northern Spy x Delicious and Jonathan x Northern Spy. The superiority of these combinations which have Northern Spy only as the common parent is interesting and agrees with the Canadian work (3) which indicated the superiority of Northern Spy as a parent in apple breeding.

If the late blooming and fruit color objectives are omitted the combination Northern Spy x Rome Beauty would roughly share top-rank with Delicious x Golden Delicious and Northern Spy x Delicious. Unfortunately, however, Northern Spy x Rome Beauty and Delicious x Golden Delicious tended to give seedlings low in percentage of over-color. Finally, if high fruit color, good quality and late harvesting period only are considered as the major objectives, Jonathan crossed with Delicious would rank as a superior combination. In this respect the progeny of McIntosh x Delicious were definitely inferior and as far as the data herein are concerned this combination was hardly superior to Gallia Beauty x McIntosh and its reciprocal.

To be sure, McIntosh x Delicious gave progeny higher in dessert quality but inferior in over-color and with a much smaller percentage of late-harvested fruits.

In general the data presented herein lend support to the conclusion that Jonathan, Northern Spy, Delicious, McIntosh and Golden Delicious in proper combinations are quite satisfactory in producing seedlings of good dessert quality. Where late blooming and late harvested seedlings are desired in addition, Northern Spy has greater possibilities in combination with the varieties of high dessert quality than any other variety while Red Spy is definitely inferior in this respect.

The tree characters of the progeny of these combinations will be presented in a subsequent paper. Suffice it to state at the moment that the combinations with Northern Spy have not been generally late in coming into flowering and in this respect the use of Northern Spy as one parent would be satisfactory.

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Ascorbic Acid Content of Apple Varieties and Seedlings at Geneva, N. Y., in 1944–1945[1]

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In the breeding and selection of agricultural crops for human consumption, attention should be directed to nutritive value in addition to such qualities as yield and disease resistance. The selection of high nutritive value products for production can become in fact one of the most practical and effective means of fostering better nutrition. Fruits are generally considered a good source of ascorbic acid (vitamin c), although apples have not generally been considered outstanding in this regard. However, even in our preliminary survey, several apple varieties or seedlings have been found containing more than 20 mg of ascorbic acid per 100 grams fresh tissue. The Calville Blanc variety, containing 37 mg/100 grams rates in ascorbic acid content superior to the tomato, equivalent to the grapefruit, and only slightly inferior to the average orange.

The hundreds of varieties and seedlings maintained at Geneva seemed to offer an excellent opportunity for a survey of the ascorbic acid content of apples. The immediate objective was simply to screen out those varieties and seedlings with particularly high ascorbic acid contents, and to consider at a later time the effect of environmental factors and horticultural practices. A total of 58 named varieties and 33 seedlings were tested in 1944, and 101 varieties and three seedlings in 1945, several of these common to each season's study.

TABLE I—The Average Ascorbic Acid Content of Some Apple Varieties and Seedlings Tested During 1944 and 1945

Variety	Ascorbic Acid (Mg/100 Grams)	
	1944	1945
Calville Blanc	37	37
Yellow Newtown	16	18
Tioga (Sutton × Northern Spy)	13	21
Late Jonathan	13	17
Orleans (Deacon Jones × Delicious)	13	13
Webster (sib. Ben Davis × Jonathan)	13	9
Newfane (Deacon Jones × Delicious)	12	15
Westchester (Ben Davis × Yellow Newtown)	11	15
Winter Banana	11	12
Jonathan	11	17
Medina (Deacon Jones × Delicious)	10	7
Yorking	9	13
Cortland (Ben Davis × McIntosh)	8	11
Saratoga (Ben Davis × Yellow Newtown)	8	10
King David	7	19
Boiken	7	8
Sweet McIntosh (Lawver × McIntosh)	7	11
Kendall (Zusoff × McIntosh)	7	5
Cox Orange	6	19
Lobo (McIntosh o.p.)	6	3
McIntosh	4	2
Davenport (McIntosh o.p.)	2	3
Station 1392 (Yellow Newtown × Northern Spy)	19	21
Station 1546 (Jonathan × Rome Beauty)	7	9

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[1] Journal Paper No. 677, New York State Agricultural Experiment Station, Geneva, N. Y., April 24, 1946.

Each of three apples of a given variety or seedling was sampled by cutting two wedge-shaped segments from opposite sides of the apple. The weighed sample (approximately 100 grams) was homogenized with an equal weight of 5 per cent metaphosphoric acid in a Waring Blendor, filtered, and the filtrate analyzed for ascorbic acid by the method of Robinson and Stotz (1). A study of the data showed that the average deviation among the three apples analyzed was ± 8.5 per cent of their mean. The general usefulness of the screening technic to

TABLE II—SUMMARY OF DATA ON THE ASCORBIC ACID CONTENT OF APPLE VARIETIES AND SEEDLINGS FOR 1944 AND 1945

Variety	Mg/100 Grams
Varieties With Exceptionally High Ascorbic Acid Content	
Calville Blanc	37*
Sturmer Pippin	29
Bramtot	25
Station 15746 (Jonathan ×Boiken)	24
Esopus	23
Opalescent	23
Station 15743 (Jonathan ×Boiken)	22
Lilydale	22
Tioga (Sutton ×Northern Spy)	21*
Station 1392 (Yellow Newtown ×Northern Spy)	21*

Varieties With 15 to 20 Mg/100 Grams

King David*, Cox Orange*, Wellington Bloomless, Perkins, Yellow Newtown*, Red Duchess (Daniels), Red Spy (Harper), Jon-a-Red, Jonathan*, Tyler, Crimson Beauty, Station 3558 (Rome Beauty ×Opalescent), Red St. Lawrence (de Rocha), Ruby Rome, Late Jonathan*, Roxbury Russet, Baldwin, Red Duchess (Van Buren), Conical Rome, Duchess of Oldenburg, Early Spy, Red Rome (Australia), Westchester (Ben Davis ×Yellow Newtown)*, Twenty-Ounce, Station 15875 (Cortland ×1401 (Yellow Newtown ×Northern Spy)).

Varieties With 10 to 15 Mg/100 Grams

Red Rome, Giant Spy (Loop), Newfane (Deacon Jones ×Delicious)*, Red Rome (Clifton), Colora, Rome Beauty, Gallia Beauty, Young, Bramley, Downing (Gallia Beauty ×Kirtland), Tioga (Sutton ×Northern Spy)*, Hubbardston, Late Jonathan*, Golden Delicious, Station 15731 [illegible]

Sweet Bough, Red Astrachan, Winter Banana*, Spiland, Golden Winesap, Northwestern Greening, LaSalle, Blue Pearmain, Crimson Spy, Red Spy (Hallenbeck), Jon-a-late, Ribston, Blackjon, Starr, Carlton (Montgomery ×Red Astrachan), Sweet McIntosh (Lawver ×McIntosh)*, Cortland (Ben Davis ×McIntosh)*, Delwine, Orleans Reinette, Westchester (Ben Davis ×Yellow Newtown)*, Arkansas, Smokehouse, Winter Banana*, Deacon Jones, Jonathan*, Winesap, Medina (Deacon Jones ×Delicious)*, Red Spy, Station 15586 (McIntosh ×Boiken), Langley Pippin, Northern Spy, Red Wealthy (Case), Conrad (Ben Davis ×Jonathan), Giant Rome (Loop), Saratoga (Ben Davis ×Yellow Newtown)*, Scarlet Beauty, Crimson Gravenstein (Hathaway), Grenadier, Emilia.

Varieties With Less than 10 Mg/100 grams

Niobe, Turley, Belle de Boskoop, Yorking*, Franklin (McIntosh ×Delicious), Staymared, Cortland (Ben Davis ×McIntosh)*, Saratoga (Ben Davis ×Yellow Newtown)*, Tompkins King, Station 1546 (Jonathan ×Rome Beauty)*, Red Baldwin (Colby), Chinook, Stark, Red Statesman, Oliver, Red Stark, Webster (sib. Ben Davis ×Jonathan)*, Haralson, Lodi (Montgomery × Yellow Transparent), Ben Davis, Chautauqua (Esopus ×Ben Davis), Early McIntosh, Urban, Sweet Delicious, White Pippin, Joan (Anisim ×Jonathan), R. I. Greening, Red Canada, Boiken*, King David*, Kendall (Zusoff ×McIntosh)*, Cox Orange*, Lobo*, Prairie Spy, Sweet Winesap, Fameuse, Richared, McIntosh, Middtun, Red Sauce (Deacon Jones ×Wealthy), Macoun (McIntosh ×Jersey Black), Pumpkin Sweet, Davenport*, Station 15739, 15736, 15741 (Jonathan × Boiken), Station 15600, 15608, 15589, 15584, 15606, 15572, 15597 (McIntosh ×Boiken), Station 15463, 15544, 15439, 15458, 15461, 15462, 15468, 15467, 15464 (Boiken ×McIntosh), Station 1509, 15193, 3910, 15367, 1546 (Jonathan ×Rome Beauty)*, 15837, 15473, Boiken*, Easter Orange Erickson, Minnesota 790, Medina (Deacon Jones ×Delicious)*, Peerless, Williams, Welday Jonathan, Kendall (Zusoff ×McIntosh)*, Lawfam, Macoun (McIntosh ×Jersey Black)*, Rhoda, Lobot*, Minnehaha, Hume, Davenport*, Red McIntosh (Rogers).

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*These varieties were tested in 1944 and 1945; see Table I.

select varieties of high or low ascorbic acid content is illustrated by the data of Table I, in which the results of two seasons are compared.

The results support the general usefulness of the screening technic, although the great discrepancy in the values for 1944 and 1945 in the case of King David and Cox Orange illustrate the need for successive year's study even with the limited objectives of the present survey. Nearly all of the 1945 results are higher than those of 1944, a finding which may be related to the abnormally small yield per tree during the latter season.

Table II summarizes the results of the two season study, the varieties divided by arbitrary ranges of ascorbic acid content.

Thirty-three apple seedlings were tested and of these four had ascorbic acid values above 15 mg per 100 grams. There is some indication that the ascorbic acid content of the parents was transmitted to the offspring. Out of six Jonathan x Boiken crosses, half ranged high in ascorbic acid like the parent Jonathan, while the other half had a low value characteristic of the Boiken. In the McIntosh x Boiken and Boiken by McIntosh crosses, all of the offspring were relatively low in ascorbic acid, as were the parents. In two crosses having Yellow Newtown as one of the parents, the ascorbic acid content was high like Yellow Newtown. Data supporting these statements are given in Table III.

TABLE III—ASCORBIC ACID CONTENTS OF PARENTS AND OFFSPRING

Variety	Mg/100 Grams
Jonathan	17
Boiken	7
McIntosh	4
Yellow Newtown	18
Jonathan × Boiken	
Station 15746	24
Station 15743	22
Station 15731	13
Station 15739	7
Station 15736	7
Station 15741	6
McIntosh × Boiken	
Station 15586	10
Station 15600	10
Station 15608	10
Station 15589	9
Station 15584	6
Station 15606	5
Station 15572	3
Station 15597	3
Boiken × McIntosh	
Station 15463	8
Station 15444	7
Station 15439	5
Station 15458	5
Station 15461	4
Station 15462	4
Station 15468	4
Station 15467	3
Station 15464	2
Yellow Newtown × Northern Spy	
Station 1392	19
Ben Davis × Yellow Newtown	
Westchester	15

CONCLUSIONS

A screening technic to distinguish high and low ascorbic acid apples has been applied during 1944 and 1945 to a part of the Geneva collection of apple varieties and seedlings. Several high ascorbic acid varieties, with the Calville Blanc outstanding, have been noted. Preliminary results indicate that a high ascorbic acid characteristic may be transmitted from parent to offspring.

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Vigor of Pistacia Seedling Progenies During First Season in Nursery

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MORTALITY attendant upon transplanting and high cost of trees are the principal difficulties encountered in establishment of a pistachio nut[1] orchard. For this reason, among others, all nursery practices and materials involved in raising pistachio nut trees should receive close scrutiny. Observation indicates that the mortality is connected with meagerness of lateral roots, whether the trees have been transplanted or remain *in situ*. Increased age fails to increase the quantity of regeneration points in the region retained by any practicable system of digging. Consequently any procedure or material that will produce the maximum number of roots in relation to the size of the top should, other things equal, reduce transplantation mortality; its advantage in decreasing cost of production of trees is obvious.

Ordinarily, only a portion of the seedlings growing from seed sown in March will reach diameter suitable for receiving the rather large pistachio bud in the ensuing September. If the relatively few eligible seedlings are budded at that time, they must either be dug by hand after one year's growth of the whip or stay an additional year, and then be dug with two year tops along with those budded on two year old seedlings, making the seedling roots three years old. At Chico root pruning or transplanting of seedlings at the end of the first year, though they increase the number of regeneration points, has generally so checked growth that budding is not practicable in the second year. Initial vigor of pistacia seedlings, whether they are to be budded in the nursery or topworked in the orchard, consequently assumes considerable importance, though the effect of heredity on regeneration and type of root, and subsequent bearing on compatibility and adaptability, cannot be ignored. The present paper confines itself to discussion of differences in initial top growth vigor found in seedling progenies.

MATERIAL AND METHODS

Seed of the widest possible range of parents was collected from trees in the pistacia collection at the United States Plant Introduction Garden at Chico, California, in the autumn of 1939, and a comparative study of the nursery growth of these seedling progenies was made in 1940. Open pollinated seed used in this study was collected from trees of five varieties and 16 numbered seedlings of *Pistacia vera* L., 10 of *P. chinensis* Bunge, four of *P. atlantica* Desf. and two of *P. terebinthus* L. Hybrid seed was available from 1939 pollinations between Pistacia species (1). After the nuts had been harvested in September of 1939 uniform seed samples of each were selected, stored in a dry place at a temperature of 70 degrees F until the following spring, and planted in a field nursery. As the Vina silt loam on the nursery site was not sufficiently sandy or porous to provide a well drained bed, and the soil tended to form a crust after each rain or irrigation, the seed was planted 4 inches apart in furrows previously filled with sand to a depth of 4 inches. The seeds were covered with a loose, friable mixture of peat and sand. One 100-seed lot of each of the *P. vera* selections was planted at random in each of six blocks. Larger lots of open pollinated seed of the smaller seeded Pistacia species were sown to provide for the uncertainties of germination and their seedlings thinned to comparable spacing soon after emerging from the ground. The smaller lots of seed resulting from controlled crosses between certain of the Pistacia species were planted at random in two adjoining blocks, replications of each varying from two to seven, depending on amount of seed available. Growth records were made also on additional lots of 1939 hybrid seed used for other studies, but released and planted on another nursery site in 1942.

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[1] The name pistachio nut is used in this paper for *Pistacia vera*, which produces the pistachio nut of commerce. The term pistacia is used in reference to the species of Pistacia in general.

The nursery was cultivated, fertilized, and irrigated uniformly as needed, and thrip and aphid infestations were controlled by spraying and dusting. At the proper time for budding, trunk diameter at approximately ¾ inch above ground and tree height measurements were made on the first 25 trees of each replicate in the first six blocks and on up to 25 trees on the smaller plots in the additional blocks. Measurements were begun September 10 and completed block by block over a period of 12 days.

Percentage buddability of each lot of seedlings was also estimated at this time, based largely on trunk diameter. In the *Pistacia vera* progenies, however, branching habit and smoothness of bark at base of seedling assumed some importance in this determination.

RESULTS

Growth data on both the 1940 and 1942 nurseries is presented in Table II. Germination of seed in the six *Pistacia vera* blocks ranged from 39.5 to 70.6 per cent, with a mean of 57.3 per cent. No perceptible differences in growth accompanied this variation in stand of trees however. The ten varieties used in determining the significance of growth variations among the seedling progenies were those of greater uniformity of stand, that is, a germination range of from 55.1 to 67.3 per cent and a mean of 60.4 per cent. Growth of trees in block 5 was uniformly poorer than that in the remaining blocks, and it was not included in final tabulation. From analysis of data given in Table I on height and diameter of seedlings, it appears that the seedling progeny of the different *P. vera* varieties differed significantly in height but not in diameter. The mean diameter of 7.9 millimeters, representing that of the 10 *P. vera* types analyzed, is close to the 8.0 millimeters mean diameter of all 21 studied.

Significant variation in height was present among the variety progenies. If height of tree at the end of one year's growth in the nursery were the only consideration, Sfax seedlings, for example, with an average height of 69.8 centimeters would be preferred to those of P.I. 80453, whose average height was 45.7 centimeters.

TABLE I—ANALYSIS OF VARIANCE FOR NURSERY GROWTH OF TEN *Pistacia Vera* SEEDLING PROGENIES (1940)

Source of Variation	Degrees of Freedom	Height		Diameter		F Required At .05 Level
		Mean Square	F Found	Mean Square	F Found	
Total	49	—	—	—	—	—
Blocks . .	4	45.48	5.76*	0.59	1.15	2.63
Varieties .	9	21.18	2.68	1.06	2.05	2.15
Error . .	36	7.89	—	18.58	—	—

*Significant at .01 level.

TABLE II—GROWTH OF PISTACIA SEEDLING PROGENY FROM GERMINATION TO BUDDING STAGE (1940 AND 1942 RESULTS)

Seed Parent	Pollen Parent	Number of Plants Measured		Average Diameter (Mm)		Average Height (Cm)		Per Cent Buddable (All Plants)	
		1940	1942	1940	1942	1940	1942	1940	1942
Pistacia vera	*P. integerrima*	206	56	10.4	16.0	72.9	134.9	74.0	98.0
P. vera	*P. atlantica*	194	140	8.2	13.0	64.5	100.3	56.1	93.0
P. vera	*P. terebinthus*	152	204	8.6	11.3	56.9	78.7	64.0	76.0
P. vera	*P. chinensis*	204	90	8.5	9.3	61.7	83.1	59.6	52.0
P. vera	*P. vera*	765	453	7.3	10.9	49.8	66.8	45.6	67.0
P. vera	Open*	10,577	—	8.0	—	58.2	—	70.1	—
P. atlantica	*P. atlantica*	—	10	—	10.0	—	71.1	—	30.0
P. atlantica	*P. terebinthus*	—	31	—	10.8	—	73.2	—	48.4
P. atlantica	Open	800	—	3.3	—	37.8	—	10.0	—
P. terebinthus	*P. terebinthus*	7	8	4.1	4.8	14.0	35.6	0.0	0.0
P. terebinthus	Open	400	—	3.6	—	23.4	—	0.0	—
P. terebinthus	*P. atlantica*	25	25	5.5	10.0	25.9	61.0	28.0	72.0
P. chinensis	*P. chinensis*	25	8	5.6	4.0	41.0	38.1	16.0	0.0
P. chinensis	Open	1,500	—	3.7	—	40.1	—	9.0	—
P. chinensis	*P. integerrima*	25	—	4.5	—	43.2	—	4.0	—

*Undoubtedly contains some species hybrids.

No attempt was made to analyze differences in growth among the open pollinated progenies of *Pistacia atlantica*, *P. terebinthus* and *P. chinensis*, the majority of the 1940 seedlings of these species being too small to bud at the time measurements were taken. Increased growth made by seedling progeny of *P. atlantica* and *P. terebinthus* in 1942 on another field reflected the more favorable nursery site but the percentage of seedlings buddable the first season was still relatively low.

Greater vigor and high buddability were found, however, among the progenies of interspecific hybrids. An increase in average diameter, over that of *Pistacia vera* sib progenies, of from 3.7 to 46.8 per cent and in height of from 14.1 to 62.3 per cent, was found among the progenies obtained by crossing four *P. vera* varieties with *P. integerrima* Stewart, *P. atlantica*, *P. terebinthus* and *P. chinensis*. Corresponding growth increases were not found in the relatively small lots of other interspecific hybrids studied except in the 1942 trials of *P. terebinthus* x *P. atlantica*. Apparently hybridity does not automatically produce vigorous seedlings in all cases.

Pistacia vera varieties crossed with pollen of *P. integerrima*, *P. atlantica* and *P. terebinthus* produced a high percentage of upright seedlings with few, if any, low branches; however, when sib-crossed they produced many semi-upright to bushy trees with low branching tendencis. This characteristic was pronounced enough to interfere with ready budding in many individuals of these progenies.

Discussion

Though seedlings of a number of Pistacia species have been suggested for use as rootsocks for pistachio varieties, presumably because of drought resistance, vigor, or other favorable characteristics of parent species in their native habitat, their adaptation to nursery and transplanting operations has not been carefully considered. The need for high initial vigor has been explained.

The tap rooting tendency of seedlings used as rootstocks requiring removal from nursery at least at the end of two seasons' growth, and the moderate to large size of pistachio variety buds, place a premium on seedling progenies with capacity for early, vigorous growth in the nursery. A search among progeny of Pistacia species other than *P. vera* failed to reveal such types and although *P. vera* progeny partially fills the need, lack of variation in growth lines within this species affords little, if any, opportunity to select more vigorous types.

Although some interspecies crosses gave negative results, those in which *Pistacia vera* was used as the female parent, produced seedling progenies of relatively high vigor and good form, a very high percentage of which were buddable the first season in the nursery.

Though factors other than those considered in these studies may eventually enter into the selection of pistachio rootstocks, the variation in growth of seedling progenies here reported suggests the possible gains to be derived from selection of parents of seedlings upon which pistachio nut varieties are to be propagated.

Unless it can be shown that seedlings of pure *Pistachia chinensis, P. terebinthus* and *P. atlantica* are sufficiently outstanding in drought resistance, compatability, or some other characteristics of importance, their nursery performance in these studies would rule them out of further consideration as rootstocks for the pistachio nut.

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Identification of Hybrid and Nucellar Citrus Seedlings by a Modification of the Rootstock Color Test

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In most varieties of citrus a large proportion of the seedlings produced are from nucellar embryos.

In citrus breeding investigations it is desirable, for economic reasons, to rogue out the nucellar seedlings as soon as they can be distinguished from the true hybrid (zygotic) seedlings, instead of giving them the space and care required to grow them to maturity. In some instances the hybrid seedlings can be distinguished from the relatively uniform nucellar seedlings by differences in size, growth habit, leaf shape, or other morphological features. By this method, however, separation is often uncertain, especially if the observer has not acquired a knowledge, in minute detail, of the characteristics of the parent varieties.

This paper reports the results of an attempt to distinguish between hybrid and nucellar seedlings by means of a chemical color test. The rootstock-bark color test of Halma and Haas (1) was adapted to the rapid testing of large numbers of small samples of leaves.

Materials and Method

Identification tests were made on over 3,800 seedlings, which were grown from seed obtained in 37 crosses. These crosses involved several species of citrus, two interspecific hybrids, and several intergeneric hybrids of citrus and related genera.

The crosses were made and the seedlings grown in connection with the citrus breeding program of the U. S. Subtropical Fruit Field Station, Orlando, Florida. In these crosses the following citrus varieties were used: *Sweet orange varieties (Citrus sinensis* [L] Osbeck), Jaffa, Norris, Navel, Hamlin, Parson Brown, and Valencia. Grapefruit varieties (*Citrus paradisi* Macf.), Marsh, Duncan, Foster, Thompson, Leonardy, and Mott. Tangelo varieties, Orlando and Minneola, which are interspecific hybrids between grapefruit and tangerine (*C. reticulata* Blanco); and tangor (*C. reticulata* x *C. sinensis*). Intergeneric hybrids, Morton citrange (*Poncirus trifoliata* [L] Raf. x *C. sinensis*), citrumelo (*P. trifoliata* x *C. paradisi*), citrangor (citrange x *C. sinensis*), *citrangelo* (citrange x *C. paradisi*). Clementine *(C. reticulata)*. Mott and Clementine are possibly interspecific hybrids, but their parentage is unknown.

In preliminary work on methods of identifying citrus seedlings all of the chemical tests described by Halma and Haas (1) and a number of others were tried. Of those tried the most satisfactory for the purpose was the Almen reagent color test adapted by Halma and Haas for use on water extracts of dried bark powder. It was found that this test worked equally well on water extracts of dried leaf powder. The use of leaves rather than bark for identification tests of seedlings has several advantages. Leaves provide relatively uniform tissue that is easily sampled, dried, and ground; and, of great importance in this work, the removal of a leaf sample is less damaging to the seedling than removal of a bark sample. Since the number of samples that had to be handled was large and many of the seedlings were so small that they bore only 10 or 12 small leaves, the methods used had to be designed for rapid handling of small samples. The modified method as finally used is summarized below:

1. Several leaves (enough to provide a 0.2- to 0.5-gram sample of dry powder) were collected from each seedling of a cross. At the same time leaves of about the same age were taken from the parent varieties. The samples were dried at 40 to 45 degrees in a forced-draught oven. Browning of the leaves during drying was avoided. The dry samples were ground to pass a 60-mesh screen in a medium-sized Wiley mill.

2. Samples of 0.2 to 0.5 gram (preferably 0.5) of leaf powder were weighed, transferred to small beakers, and extracted overnight in 5 ml of distilled water per 0.1 gram of sample (sets of 24 seedling samples from a given cross and one or two samples from each parent variety were run together).

3. The extract was filtered through rapid paper, and 2 ml of filtrate was pipetted into a 3 x ½-inch test tube. Each set of tubes containing 24 seedling samples and the pair of parent samples were supported in a metal serological tube rack.

4. To each 2-ml sample of filtrate in a tube the following solutions were added in the order listed:

   2 drops of potassium hydroxide (25 grams per 100 ml water stock solution diluted; 1 part KOH to 20 parts water).
   2 drops copper sulfate solution (saturated)
   2 drops Almen reagent (160 grams mercury dissolved in 100 ml fuming nitric acid [sp.g. 1.60] and diluted with 320 ml water.).

5. The test tube rack was shaken vigorously to mix the contents of the tubes and placed in a boiling water bath. The tubes were heated until the heavy precipitate that formed reached full color. The rack was then removed from the bath and shaken vigorously. When the precipitate had settled a visual comparison was made of the color (shade and intensity) of the solutions from the parents and seedlings.

After the leaf samples were collected, three workers could run about 100 samples per day by this procedure.

It was found, as expected, that the color of the nucellar seedling solutions matched the female parent solution, but that in almost all varieties the intensity of color was slightly less in the nucellar seedling solutions than in the female parent solutions. Why this is true is not known. Sometimes slight variations probably resulted from the difficulty of collecting leaves of the same age from the seedlings and the parent trees. Solutions that showed a difference in shade of color or a marked difference in intensity of color from that of the female parent solution were judged to be from hybrid seedlings. The solution from the male parent was useful only as an indication of what might be expected from the hybrid. That is, the colors of solutions from the hybrids were sometimes intermediate between the two parents or occasionally about the same as the male parent, and rarely the intensity of color of the hybrid seedling solution was greater than that of either parent.

Results and Discussion

The results of the seedling tests are shown in Table I. The seedlings from all of the crosses were examined by a skilled observer and the seedlings of most of the crosses were classified on the basis of morphological characters as hybrid or nucellar. The seedlings of a few crosses in which Clementine was used as the female parent were not classified on the morphological basis because of the uncertainty of judgment in these groups.

TABLE I—Hybrid and Nucellar Citrus Seedlings Identified by Color Tests and Morphological Characters

Cross	Number of Seedlings	Hybrids Identified by Color Test	Hybrids Identified by		Number of Hybrids Identified Common to Both Methods	
			General Character	Trifoliate Leaves	General Character	Trifoliate Leaves
Marsh × citrangelo	24	4	3	5	—	3
Davis × citrangelo	46	11	8	10	—	4
Navel × citrangor	19	3	1	2	—	2
Duncan × citrangelo	39	10	4	5	1	5
Duncan × citrumelo	46	22	5	1	3	1
Foster × citrumelo	216	103	23	32	12	24
Clementine × citrangor	31	31	16	15	16	15
Clementine × Morton	12	12	—	10		10
Clementine × Mott	253	253	57	—	57	—
Clementine × Hamlin	25	25	2	—	2	—
Clementine × Orlando	327	327	—	—	—	—
Clementine × Minneola	277	277	—	—	—	—
Clementine × tangor	359	359	—	—	—	—
Clementine × Davis	19	19	—			
Orlando × Hamlin	343	38	31	—	11	—
Mott × Hamlin	252	50	64	—	37	—
Mott × Davis	105	72	29	—	24	—
Mott × Foster	36	21	7		6	
Mott × Clementine	48	7	3	—	1	—
Jaffa × Mott	5	2	2	—	2	—
Jaffa × Thompson	32	6	7	—	2	—
Jaffa × Leonardy	150	19	23	—	6	—
Jaffa × citrangor	50	3	6	—	3	—
Jaffa × citrangelo	3	0	0	—	—	—
Satsuma × citrangelo	11	0	0	—	—	—
Satsuma × citrangor	11	0	0	—	—	—
Parson Br. × citrangor	102	42	7	—	3	—
Davis × citrumelo	8	6	4	—	4	—
Orlando × tangor	70	13	9	—	1	—
Marsh × Hamlin	14	4	3	—	3	—
Marsh × citrumelo	45	9	2	—	2	—
Foster × Mott	158	32	12	—	4	—
Foster × Hamlin	42	0	0	—	—	—
Norris × Mott	37	7	10	—	5	—
Thompson × Morton	5	0	0	—	—	—
Minneola × Clementine	580	117	98	—	69	—
Tangor 653 × Valencia	51	3				
Totals	3851	1907	436	80	274	64

In Table I the number of seedlings of each cross that were identified as hybrid by the color test and the number identified as hybrid by morphological characters are shown. In addition, the number of seedlings that had trifoliate leaves, and the number of these trifoliate plants that were identified by the color test (column 7) are listed. Since, in the crosses involving parents with trifoliate leaves the trifoliate plants were used as male parents, it is certain that all of the trifoliate progeny are hybrid. The number of trifoliate seedlings identified that were common to both methods (column 7) as compared to the total number tested (column 5) gives some notion of the reliability of the color test. In a comparison of the number of seedlings from the several crosses identified by each method as hybrid, with the number common to both methods of identification (columns 3, 4, 6, and 7), it is apparent that agreement is fairly close, and is considerably better in most cases than would be expected from chance alone.

Even excluding the Clementine seedlings that were not classified by the morphological method, the number of seedlings selected as hybrid by the color test greatly exceeds the number selected by morphological characters.

When the seedlings selected as hybrid by the color test and by general morphological characteristics come into bearing it will be possible to classify them as hybrid or nucellar on the basis of fruit characters. While classification based upon fruit characteristics is also not infallible, it is the best method available, and later should serve as a measure for testing the reliability of the two methods used to classify the young seedlings.

Color tests made upon extracts from the parent varieties involved in these crosses, exhibited a considerable color range, from a dark pink or claret wine in the case of Clementine and tangor, through light bright pink in the sweet orange varieties and in Orlando and Minneola, to pale lavender in some *P. trifoliata* hybrids, and to pale pinkish amber in the grapefruit varieties, and to almost colorless in *Poncirus trifoliata*. When a cross was between parents that gave a striking color difference, it could reasonably be expected that nucellar seedlings would give a color reaction similar to that of the female parent, while most hybrids would be intermediate between the parents in color, and either lighter or darker than the female parent, depending on the direction of the cross. In general, results substantiated expectations, but exceptions were not uncommon. A few seedlings of Clementine x tangor were greenish amber instead of pink. One Clementine x Davis seedling gave a lemon-yellow solution.

The method outlined here is probably nearly useless as a tool for selecting hybrids from crosses between varieties of the same species, and of little use between any parents that have similar color reactions, for example Marsh x citrumelo. These two varieties both yield from the color test pale pinkish amber solutions that are almost identical. However, several hybrids were detected in this cross because their solution colors were darker than the others.

Crosses involving Clementine as the female parent were bewildering and discouraging during the first season's work. Color reactions from every one varied so that no two were a perfect match, and the conclusion was reached that few if any nucellar seedlings occurred. In the progeny of Clementine x Morton, 10 out of the 12 seedlings bore trifoliate leaves, while in the 31-plant progeny of Clementine x citrangor 15 were trifoliate and 16 were considered hybrid because of other morphological characteristics. Both Morton (a citrange) and citrangor are intergeneric hybrids and therefore heterozygous for the trifoliate leaf character. Therefore when they are back-crossed to the simple-leafed recessive, segregation can be expected to occur and to produce hybrids that do not have trifoliate leaves. Those facts seemed to substantiate the results of the color test. To further check on these conclusions, Clementine was crossed with *Poncirus trifoliata* as male parent to introduce the dominant trifoliate character into every zygotic embryo. Then any simple-leafed plants could with certainty be considered a Clementine nucellar seedling. Several hundred seeds from this cross were planted. Every seedling had trifoliate leaves, and no twin seedlings appeared. Therefore these facts were accepted as evidence that probably no nucellar seedlings are produced when Clementine is used for the female parent. These facts secured a year later helped to substantiate the conclusions reached from the earlier color tests.

The results of color tests on the citrus species and hybrids used as parents in the crosses described here, as well as tests run on a few other citrus species and citrus relatives, suggest that the color test might be of use as an indication of the possible parentage of hybrids of unknown origin. For example, a pale lavender color will indicate that grapefruit and *P. trifoliata* were probably involved in a hybrid showing this color, or dark claret-wine color would indicate that *C. reticulata* or possibly one of its hybrids was involved in the cross.

Since the number of hybrids identified by the color test, as well as by general morphological characteristics, was small in crosses involving Orlando, Minneola, and Tangor 653 as female parents, the potentiality of hybrid production by these parents was investigated by crossing them with *P. trifoliata* as the male parent. Out of several hundred seedlings from each cross Orlando produced no trifoliate plants, Minneola two, and Tangor 653, none. Many twin and triplet seedlings were produced by the seeds of these varieties, which further emphasizes the tendency toward the production of nucellar embryos and suppression of the development of zygotic seedlings. On the other hand, Temple orange (from color tests, judged by the authors to be a tangor), crossed with *P. trifoliata* as the male parent, produced only one seedling per seed, and all seedlings were trifoliate. This indicates that the Temple orange, like Clementine, produces only zygotic seedlings.

SUMMARY

The rootstock color test of Halma and Haas was adapted to rapid testing of large numbers of small samples of citrus leaves; and the method was applied in an attempt to distinguish between hybrid and nucellar seedlings. Data are presented on identification tests which were made on over 3,800 seedlings obtained in 37 crosses involving several intergeneric hybrids of citrus and related genera. This color test offers an additional method to aid in the selection of zygotic citrus seedlings in the process of roguing nucellar seedlings. Because of the

cost involved these numerous nucellar seedlings cannot be carried on to maturity for more positive identification.

LITERATURE CITED

1. HALMA, F. F., and HAAS, A. R. C. Identification of certain species of citrus by colorimetric tests. *Plant Physiol.* 4: 265–268. 1929.

Estimating Heights of Citrus Trees[1]

By F. M. TURRELL, *University of California Citrus Experiment Station, Riverside, Calif.*

THE hypsometer designed by F. G. Plummer has long been used by the U. S. Forest Service for estimating the heights of trees. This instrument, manufactured by Keuffel and Esser Co. (their No. 5724), consists of a brass case 3⅝ inches in diameter, in which is mounted a sensitive pendulum clinometer, graduated to percentage of angle, from 0 to 200 per cent for elevation. Its size and cost make it a very convenient and inexpensive instrument for estimating the heights of citrus trees and other small trees, and only one observer is required when certain precautions are taken.

Instructions (1) which accompany the instrument are designed for finding the height of tall trees, where the height of the observer contributes only a negligible error. But in finding the height of citrus trees and other small trees, the height of the observer's eye from the ground is an important feature of the calculations. In Table I the heights of trees corresponding to various percentages of elevation are presented; in these the height of the observer's eye is taken into account. Since all eye heights could not be included, three have been selected, namely, those 5, 5½, and 6 feet from the ground.

For trees of small height, sufficient precision is not possible by holding the instrument in the hand, as designed; the instrument must be mounted on a stick so that its center (about which it must turn) is 5, 5½, or 6 feet from the ground. A satisfactory mounting for the hypsometer on a folding 5-foot stick is shown in Fig. 1. In use, the stick must be held vertical to the ground, as small variations from the vertical change the percentage of elevation readings substantially. If this is not easily done by the observer, a plump bob and a brace provided with a slot and bolt should be added to the instrument.

PROCEDURE

When the observer has mounted the hypsometer on a 5-, 5½-, or 6-foot stick and stands so that the hypsometer center is 25 feet from a point directly below the highest point of the tree (Fig. 2), tree height may be obtained directly from percentage elevation readings by referring to Table I.

The percentage elevation, *E*, is read directly from the hypsometer, and the equivalent argument values are located in Table I, column "*E*." The value of the function (tree height in feet) corresponding to a given value of *E* is found in one of the adjacent columns. If the hypsometer height, x' (Fig. 2), is 5 feet from the ground, use the column in Table I headed "$x' = 5$"; if $x' = 5\frac{1}{2}$ feet, use the column headed "$x' = 5\frac{1}{2}$"; and if $x' = 6$ feet, use the column headed "$x' = 6$," except when *E* is 130 per cent or over, in which case the observer need only use the column "$x' = 5$," as the variation of 1 foot in the ob-

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[1] Paper No. 551, University of California Citrus Experiment Station, Riverside, California.

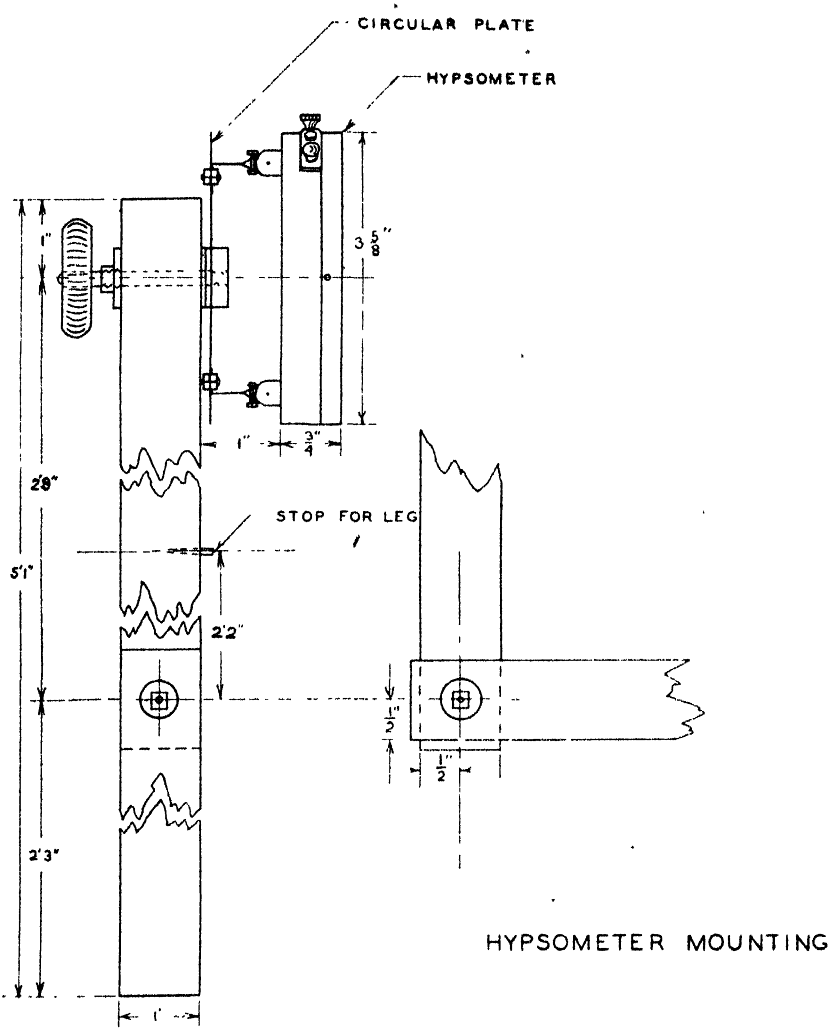

FIG. 1 Diagram showing method of mounting hypsometer on a folding 5-foot stick.

server's height does not materially affect the value of x (the tree height) for greater angles of elevation. Where the angles are greater than 130 per cent, some difficulty will be experienced by the investigator in getting into position to make the observations. If one is using a 5-foot hypsometer mounting for angles smaller than 130 per cent, a 5½-foot mounting will reduce this difficulty for angles above 130 per cent. To obtain the values given in Table I, the length of x'' (Fig. 2) was calculated from E, and this value was added to x' (5 feet, 5½ feet, or 6 feet, as required) to give the value x (the height of the tree). It is assumed that all percentages of elevation will be obtained with the

TABLE I—HEIGHTS OF TREES (x), IN FEET, CORRESPONDING TO PERCENTAGE ELEVATIONS (E) FOR A BASE LINE OF 25 FEET AND HYPSOMETER HEIGHTS (x') OF 5, 5½, AND 6 FEET

E (Per Cent)	Tree Height (Feet) When			E (Per Cent)	Tree Height (Feet) When		
	$x' = 5$	$x' = 5\frac{1}{2}$	$x' = 6$		$x' = 5$	$x' = 5\frac{1}{2}$	$x' = 6$
0	5.0	5.5	6.0	92	28.0	28.5	29.0
2	5.5	6.0	6.5	94	28.5	29.0	29.5
4	6.0	6.5	7.0	96	29.0	29.5	30.0
6	6.5	7.0	7.5	98	29.5	30.0	30.5
8	7.0	7.5	8.0	100	30.0	30.5	31.0
10	7.5	8.0	8.5	102	30.5	31.0	31.5
12	8.0	8.5	9.0	104	31.0	31.5	32.0
14	8.5	9.0	9.5	106	31.5	32.0	32.5
16	9.0	9.5	10.0	108	32.0	32.5	33.0
18	9.5	10.0	10.5	110	32.5	33.0	33.5
20	10.0	10.5	11.0	112	33.0	33.5	34.0
22	10.5	11.0	11.5	114	33.5	34.0	34.5
24	11.0	11.5	12.0	116	34.0	34.5	35.0
26	11.5	12.0	12.5	118	34.5	35.0	35.5
28	12.0	12.5	13.0	120	35.0	35.5	36.0
30	12.5	13.0	13.5	122	35.5	36.0	36.5
32	13.0	13.5	14.0	124	36.0	36.5	37.0
34	13.5	14.0	14.5	126	36.5	37.0	37.5
36	14.0	14.5	15.0	128	37.0	37.5	38.0
38	14.5	15.0	15.5	130	37.5	38.0	38.5
40	15.0	15.5	16.0	132	38.0	38.5	39.0
42	15.5	16.0	16.5	134	38.5	39.0	39.5
44	16.0	16.5	17.0	136	39.0	39.5	40.0
46	16.5	17.0	17.5	138	39.5	40.0	40.5
48	17.0	17.5	18.0	140	40.0	40.5	41.0
50	17.5	18.0	18.5	142	40.5	41.0	41.5
52	18.0	18.5	19.0	144	41.0	41.5	42.0
54	18.5	19.0	19.5	146	41.5	42.0	42.5
56	19.0	19.5	20.0	148	42.0	42.5	43.0
58	19.5	20.0	20.5	150	42.5	43.0	43.5
60	20.0	20.5	21.0	152	43.0	43.5	44.0
62	20.5	21.0	21.5	154	43.5	44.0	44.5
64	21.0	21.5	22.0	156	44.0	44.5	45.0
66	21.5	22.0	22.5	158	44.5	45.0	45.5
68	22.0	22.5	23.0	160	45.0	45.5	46.0
70	22.5	23.0	23.5	162	45.5	46.0	46.5
72	23.0	23.5	24.0	164	46.0	46.5	47.0
74	23.5	24.0	24.5	166	46.5	47.0	47.5
76	24.0	24.5	25.0	168	47.0	47.5	48.0
78	24.5	25.0	25.5	170	47.5	48.0	48.5
80	25.0	25.5	26.0	172	48.0	48.5	49.0
82	25.5	26.0	26.5	174	48.5	49.0	49.5
84	26.0	26.5	27.0	176	49.0	49.5	50.0
86	26.5	27.0	27.5	178	49.5	50.0	50.5
88	27.0	27.5	28.0	180	50.0	50.5	51.0
90	27.5	28.0	28.5	182	50.5	51.0	51.5

observer and the tree on the same ground level. For precise measurements, a 25-foot cord drawn very taut and fitted with a small cord level can be used to advantage in making adjustments.

SOURCES OF ERROR

The precision of the instrument when used in conjunction with Table I gives an estimate easily within 6 inches of actual height without using interpolation. The hypsometer scale is divided into 5 per cent divisions, and estimates can readily be made within the divisions to 1 per cent. Roughly, an increase in elevation of 4 per cent, as indicated by the table, is equivalent to 1 foot, whereas hypsometer readings may be made on the hypsometer scale with an absolute error equivalent to not more than 3 inches.

Contributing sources of error external to the hypsometer are: (a) movement of the mounting stick from the vertical, (b) deviations of

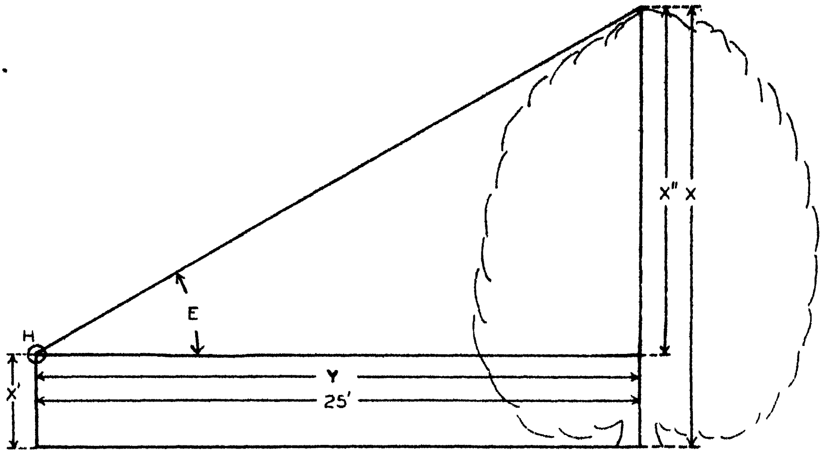

Fig. 2. Diagram showing position of observer's stick *(x')* fitted with hypsometer *(H)* by which the percentage elevation *(E)* is obtained. The base line *(Y)* is set at 25 feet in order to fit conveniently in citrus groves. The tree height *(x)* equals $x' + x''$ and is given in Table I in feet.

the base of the mounting stick from the ground level at the base of the tree trunk, and (c) vibration or lean (toward or away from the observer) of the object being measured. The last-named type of error can be a source of serious discrepancies. For instance, in measuring a 33-foot pole that leaned so that the top was 13.5 inches closer to the observer than the bottom, the reading of percentage elevation, using the 5-foot stick, was 118 per cent instead of 112.[2] If correction had not been made for the lean, the estimated height of the pole would have been 34.5 feet instead of 33 feet. The error caused by leaning of pole or tree is small for short objects and large for tall ones.

SUMMARY

Adaptations are described for use of a hypsometer in estimating the height of citrus trees. A table is included for translating hypsometer readings in per cent to tree height in feet.

LITERATURE CITED

1. Keuffel and Esser Co. Directions for the use of hypsometer no. 5724. 4 p. New York, N. Y. 1917.

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[2] The author is indebted to Mr. D. L. Slack for assistance in making this check of the table.

A Summary of Investigations on the Use of Hardy Trunk-Forming Stocks in Maine

By M. T. Hilborn and J. H. Waring, *University of Maine, Orono, Me.*

Since the severe winters of the mid-1930's there has been considerable interest on the part of several investigators in various State Experiment Stations and in Canada in the use of hardy intermediate stocks as a means of alleviating some of the losses from winter injury to apple trees. The impetus for this development has originated largely at the Iowa Station where experimentation has been conducted for some time.

The use of hardy trunk-formers has long been advocated both in the United States and in Europe. For example, Waugh (23) in 1897 when giving a brief discussion of the previous 30 years' experiences with "ironclads" both in Vermont and elsewhere mentions that tender varieties of apples should be top-worked on a hardier sort. As in other States, the benefits of top-working a tender variety were noted in Maine at least as early as 1867, and in 1899 True (20) presented definite recommendations before a fruit growers' meeting in Maine. Work was started at the Maine Station in 1892 by Munson and in 1903 he noted some stocks as being adapted to top-working (14). Orchardists in Maine, as elsewhere, were slow in adopting this practice of using hardy trunk-formers not only because of the extra work involved but also because of the uncertainty of the results. It was common practice in that early period to use wild seedlings, and stock-scion incompatibilities as well as inherent variability in stock hardiness tended to discourage the orchardist. Further, Munson (15) in 1908 reported that some of the stocks such as Arabka, Haas, Hibernal, and "other Russians" had winterkilled in the winter of 1906–07. In Europe, likewise, the practice of using hardy trunk-formers does not seem to have become common. Filewicz[1] notes that top-working of tender varieties on hardy stocks was done in Poland at Sinoleka in 1903, and that the method was also being used in various parts of central Europe.

Widespread injury to the trunks and crotches of even the hardier sorts of apples resulting from the severe winter of 1933–34 led to a revival of interest in the use of trunk-formers (*i. e.*, hardy inter-stocks) in Maine. Trunk and crotch injury was so common in Maine, even in McIntosh, that many growers had to resort to bridge-grafting and inarching in an attempt to repair the damage. Fig. 1 illustrates a typical tree in one of the large commercial orchards in Maine where over 75 per cent of the trees in a large McIntosh block were so injured. No authentic instance of root killing was observed in Maine when the injury of 1933–34 was studied and no case has been observed in subsequent winters. This lack of root injury, probably due to the usual snow cover, combined with the prevalence of trunk and crotch injury, has resulted in attention being focused almost entirely on the use of

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[1] Personal communications.

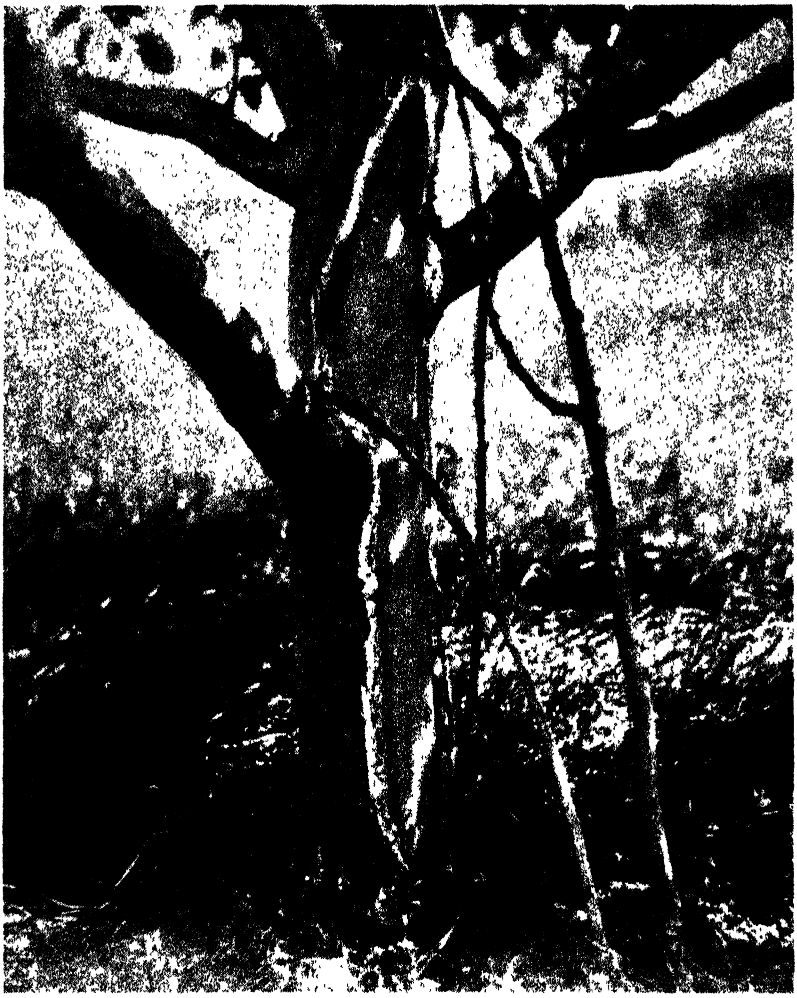

FIG. 1. McIntosh showing the kind of injury common after the severe winter of 1933–34. Inarching was a partial aid in recovery of such trees.

hardy trunk-formers. Various apple and crab apple selections of potential hardiness and desirability as trunk-formers are now under test.

General Requirements of a Trunk-Former:—The basis of selection for a trunk-former in Maine has been the possession of several of the following desirable characteristics: (1) hardiness; (2) wide crotch angle, denoting strength; (3) good branch distribution; (4) vigorous growth; (5) compatibility with apple varieties of present commercial importance and; (6) ability to form trees that can be top-worked completely in the fewest years. Of these, hardiness is the first and chief requirement. Since top-working consists of setting buds or scions in their branches at some distance from the trunk, a wide-branching trunk-forming stock will improve upon the natural form of such upright-branching varieties as Northern Spy, Early McIntosh, and Delicious. The tendency of a stock to develop a goodly number of branches early and in symmetrical arrangement is prerequisite to the development of a good orchard tree by top-working. Vigorous growth is important because a stock variety that starts well and grows vigorously may be top-worked earlier than one that lacks vigor. The stocks under test vary greatly in this respect. Compatibility, the ability of stock and scion to make good union and growth, must largely be tested although considerable information is available on some stocks that have been used elsewhere as trunk-formers. Although it would be desirable to find a trunk-forming stock that would thus unite with a large number of scion varieties, still it is conceivable that no single stock will prove best for all the apple varieties that are now, or in the future will be, important in Maine. Therefore, a stock material which possesses other desirable characteristics but is found incompatible with a particular variety or strain, is not eliminated from further consideration. Fig. 2 illustrates a typical trunk-former with some of the desirable characteristics; wide crotch angles, good branch distribution, and vigorous growth all are apparent.

Experimental plantings were begun in Maine in 1935 using Virginia Crab and Hibernal, as these two stocks were the generally accepted trunk-formers. As other trunk-formers with promise became available the test plantings were enlarged. As Maine climatic conditions vary considerably, experimental plantings were scattered throughout the State. Five plantings of at least 320 trees each and 12 smaller plantings were made. All but two of these plantings

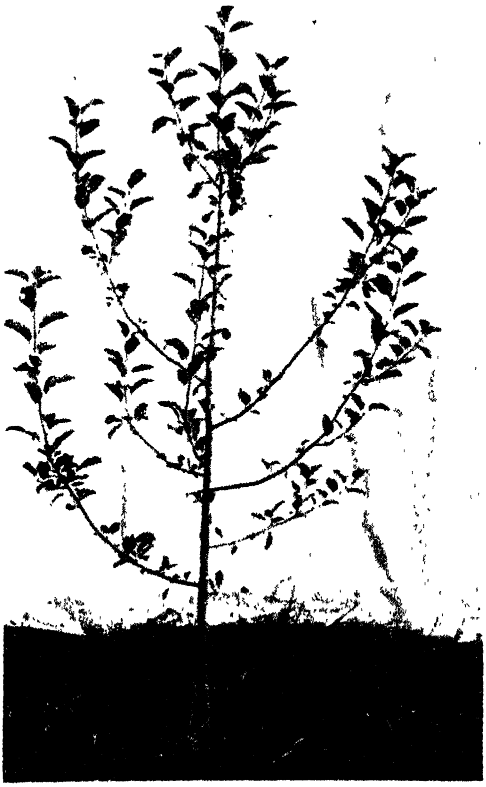

FIG. 2. A typical hardy stock ready for top-working. This tree illustrates the characteristics desired in a trunk-former. Tree is Red Standard, a Russian variety.

are managed in cooperation with commercial orchardists. Since 1935 over 40 other trunk-forming stocks have been added to these plantings. Most of these newer additions are European importations secured through the courtesy of the Division of Plant Exploration and Introduction, U. S. Department of Agriculture. Other hardy stocks have been secured from selections made at other State Agricultural Experiment Stations and in Canada, and in a few instances from wild trees found growing in Maine.

The desirability of searching for trunk-formers other than Virginia and Hibernal has been demonstrated. Following the November, 1940, freeze in the Midwest several investigators, among them Pickett and Lantz (17), noted that Virginia was not as hardy as Hibernal, while Baker (1) stated that Virginia was severely injured in 60 per cent of the cases examined and was therefore not a safe stock for use in Nebraska. Filinger (8), however, reported Virginia to be hardy in Kansas, and Hildebrandt (11) found Virginia to be uninjured in Germany during the severe winters of 1928–29 and 1939–40. Various commercial orchardists such as Clark (5) in Iowa express a preference for Hibernal, not only because of the greater hardiness but also because of the kind of tree produced with this stock. Hilborn (10) noted that Virginia seems to be the preferable stock for Baldwin as this variety winterkilled when top-worked on Hibernal. Tukey and Brase (21) recently summarized some of the literature on the congeniality of Virginia with various scion varieties and list several cases of incompatibility.

The evaluation of trunk-forming stocks is necessarily a long-time project, but sufficient data have been obtained to warrant a preliminary report on twenty five of them. Orchard survival and adequate yield records of the scion varieties will, in the final analysis, become the basis for properly establishing their merit or lack of it. Almost all seem sufficiently hardy for Maine climatic conditions, but more data should be accumulated before an attempt is made to report on the severity of conditions that they may be expected to withstand. Some evidence of the compatibility of these 25 stocks with four principal scion varieties is presented in Table I. Other varieties tried with Hibernal and which appear to be compatible with it are Baldwin, Delicious, Early Harvest, Golden Delicious, Jewett Red (Nodhead), Lodi, Red Astrachan, and Wealthy. Virginia likewise appears to be compatible with Baldwin, Duchess, Early McIntosh, Golden Delicious, Lawfam, Liveland Raspberry, Lodi, Melba, Milton, Newfane, Red Astrachan, R. I. Greening, St. Lawrence, Tolman Sweet, Wealthy, Winter Banana, and Yellow Bellflower. There is some evidence that Red Gravenstein is not entirely compatible with Virginia. There is, at least sometimes, an overgrowth of the Red Gravenstein wood. The same is true, but to a lesser extent, with Gravenstein. The combination of Tayezhnoie and Rogers McIntosh has proven incompatible as will be discussed more fully later in this report. Another form of incompatibility, the varietal difference in growth increment, may result in the discarding of some stock-scion combinations in the future. Although no instance has been noted to the present time, it is conceivable

TABLE I—PRELIMINARY NOTES ON THE COMPATIBILITY OF VARIOUS HARDY STOCKS WHEN TOP-WORKED TO FOUR COMMERCIAL APPLE VARIETIES

Hardy Stock	Scion Variety*			
	McIntosh	Cortland	Spy	Delicious
Anis (P. I. 113472)**	C	C	C	—
Antonovka Shafran (P.I. 107197)	C	C	C	C
Bellfleur Kitaika (P.I. 90524)	C	C	C	C
Charlamoff	C	C	C	C
Coulon Renette (P.I. 89799)	C	C	C	C
Dudley	C	—	—	—
Hibernal	C	C	C	C
Izo	—	—	—	C
Kulon Kitaika (P.I. 107229)	C	C	C	C
Linda (P.I. 123993)	C	—	—	—
Manitof (P.I. 113828)	—	—	—	—
Noir de Vitry (P.I. 125565)	—	C	C	—
Paragon	—	—	C	—
Pewaukee	C	C	C	—
Pippin Shafran (P.I. 104995)	C	—	—	—
Red Standard (P.I. 104996)	C	—	—	—
Robusta No. 5	C	—	—	—
Sheriff	C	—	—	—
Surpasse Frequin (P.I. 125566)	C	—	—	—
Tayezhnoie (P.I. 107253)	I	C	I	C
Transparent de Croncels (P.I. 102561)	C	—	—	—
Virginia	C	C	C	C
Virginischer Rosenapfel (P.I. 105405)	—	C	C	C
Yakhontowoye (P.I. 104999)	C	—	—	—
Wisantowoye (P.I. 104998)	C	—	—	—

*C denotes a stock-scion combination that is compatible and I one that is incompatible, while — indicates either that the stock-scion combination has not been tried or that, if tried, sufficient time has not elapsed to yield reliable data.

**The number given in parentheses is the Plant Introduction number for material received from the U. S. Department of Agriculture, Division of Plant Exploration and Introduction.

that in some stock-scion combination the stock and scion might grow at a different rate and this result in mechanical weakness.

Two of the stocks listed in Table I are definitely not recommended for Maine. Anis lacks vigor and its crotch angles are narrow. Wisantowoye seems more vigorous than some others, but its crotch angles are narrow and tend to be weak. Paragon and Pewaukee are considered doubtful at present, limited observation suggesting that both may be lacking in hardiness. Of the remaining stocks listed in Table I, eight have been considered good enough to warrant propagation on a fairly large scale for orchard planting. Of these, Hibernal and Virginia are still the most widely used, Kulon Kitaika, Charlamoff, Bellfleur Kitaika, and Antonovka Shafran are Russian varieties, Noir de Vitry is from France, and Coulon Renette is from Germany.

The newest additions to the experimental plantings include several stocks that show promise. Ten of these are from Russia: Bellfleur Phoenix (P. I. 107201)[2], Bessemianka (P. I. 107202), Cestra Belfer Kitaika (P. I. 107204), Chinese Shampanren (P. I. 107206), Filice (P. I. 107211), Flava (P. I. 107212), Krasnoznamennoie (P. I. 107227), Renet Bergamotnii (P. I. 107239), and Rubinovie (P. I. 107244). Three are from Canada: Anaros (P. I. 139664), Columbia (P. I. 123988), and Osman (P. I. 123995). Two others are native to the United States: Florence, a crab apple, and 4–7–16, a selection of the Iowa Station.

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[2] Varieties designated by P. I. numbers were obtained through the courtesy of the Division of Plant Exploration and Introduction U. S. Department of Agriculture, Glenn Dale, Maryland.

Methods of Top-working:—Satisfactory trees have been obtained in Maine by using either budding or grafting as the means of top-working. The usual practice is to bud during the second year after planting in the orchard. Then in the next spring any bud failure is whip-grafted. If this graft fails, and if the branch has become too large to whip graft, a cleft or perhaps an inlay graft may be required. Much consideration has been given to the distance at which this top-working is done on the scaffold branch. The practice in Maine has been to top-work on the branch about 18 to 24 inches from the trunk. Practice in Iowa would seem to favor top-working at a greater distance. This assumes importance not only because of the decrease in the amount of hardy crotch which accompanies an increase in trunk diameter, but also because of the probability that the relative hardiness of stock and scion will be influenced by the reciprocal action of the component parts. Filewicz in Poland favors leaving at least one branch of the intermediate stock on the southwest side of the tree, stating that hardiness is thereby imparted throughout the scion variety.

A preliminary evaluation of eight trunk-forming stocks when top-worked to McIntosh was attempted in an experimental planting at Orono. The trees used in this study were planted in 1941 in four rows 17.5 feet apart with trees 10 feet apart in the rows. Ten trees of each variety were set, and the varietal arrangement was such that the greatest number of variety-to-variety comparisons could be made. Such comparisons are made between a given tree and the two adjacent in the row, the two at right angles across the row, and the four that are diagonally adjacent. The top-working by budding was begun in 1942 and, with but few exceptions, was completed in 1945. The trunk-forming stocks used were Anis (P. I. 113472), Antonovka Shafran (P. I. 107197), Bellfleur Kitaika (P. I. 90524), Charlamoff, Hibernal, Kulon Kitaika (P. I. 107229), Tayezhnoie (P. I. 107253), and Virginia Crab. In order to afford a comparison between these and a standard apple variety of the region, 10 trees of Rogers McIntosh were included in the planting and branch-budded just as the trunk-forming stocks, using Rogers McIntosh buds. Trunk circumference, growth increment, and the number of buds inserted were recorded annually for each tree.

Branch selection was practiced at budding time to the extent that in general a single branch was budded for retention at each desired position. An occasional failure in "bud take" resulted in another year being required to establish a branch of the scion variety in such position. However, no consistent varietal differences were found to be associated with such bud failures and their occurrence caused no appreciable lengthening of the time necessary to develop the trees.

Since trunk circumference seems to be a reliable indicator of tree growth and potential productivity, it was used as one means of comparing the nine varieties. The end results of these comparisons, treated by Student's method, are presented in Table II. A significant difference between two varieties is noted by placing at the coordinate point

TABLE II—COMPARISONS BETWEEN THE CIRCUMFERENCES IN 1945 OF VARIOUS TRUNK-FORMING STOCKS. AN INITIAL LETTER INDICATES A SIGNIFICANT DIFFERENCE AND SHOWS WHICH IS GREATER

Material	Anis	Antonovka Shafran	Bellfleur Kitaika	Charlamoff	Hibernal	Kulon Kitaika	McIntosh	Tayezhnoie
Antonovka Shafran	—	—	—	—	—	—	—	—
Bellfleur Kitaika	B	—	—	—	—	—	—	—
Charlamoff	C	—	—	—	—	—	—	—
Hibernal	—	A	B	C	—	—	—	—
Kulon Kitaika	—	—	—	—	K	—	—	—
McIntosh	A	A	—	C	—	K	—	—
Tayezhnoie	—	—	B	—	—	K	T	—
Virginia Crab	V	—	—	—	—	—	V	V

the initial letter of the variety that was the larger. Charlamoff, Bellfleur Kitaika, Kulon Kitaika, and Virginia Crab rate well in these growth comparisons. Each is significantly larger than three other varieties. Also in every instance, except two with Kulon Kitaika, the differences were significant at the 1 per cent level. The greater vigor of these trunk-formers becomes apparent when it is seen that six of the eight have surpassed the Rogers McIntosh in growth, and significantly so.

In Table III is presented a similar comparison based on the trunk growth increment of 1945. There Charlamoff and Bellfleur Kitaika appear to the best advantage, Charlamoff differing significantly from four other varieties and Bellfleur Kitaika from three.

TABLE III—COMPARISONS BETWEEN THE TRUNK GROWTH INCREMENTS IN 1945 OF VARIOUS TRUNK-FORMING STOCKS. AN INITIAL LETTER INDICATES A SIGNIFICANT DIFFERENCE AND SHOWS WHICH IS GREATER

Material	Anis	Antonovka Shafran	Bellfleur Kitaika	Charlamoff	Hibernal	Kulon Kitaika	McIntosh	Tayezhnoie
Antonovka Shafran	—			—	—	—	—	—
Bellfleur Kitaika	B	—	—	—	—	—	—	—
Charlamoff	C	—	—	—	—	—	—	—
Hibernal	H	—	—	—	—	—	—	—
Kulon Kitaika	—	—	—	C	—	—	—	—
McIntosh	—	—	B	C	—	K	—	—
Tayezhnoie	—	A	B	—	H	—	—	—
Virginia Crab	—	—	—	C	H	—	V	V

Each tree was examined during the growing season of 1944 and again in 1945 and rated on vigor, branch distribution, and width of crotch angle, using the arbitrary scale of poor, fair, good, and excellent. In vigor Bellfleur Kitaika, Charlamoff and Virginia Crab were rated as excellent; Antonovka Shafran, Tayezhnoie, and Hibernal as good; Anis and Rogers McIntosh only as fair. In branching system Tayezhnoie and Bellefleur Kitaika were adjudged excellent; Charlamoff, Virginia Crab, Kulon Kitaika, Antonovka Shafran, and Anis as good; Hibernal and Rogers McIntosh as fair. In width of crotch angle, 90 degrees being the arbitrary standard, a rating of excellent was given to Tayezhnoie, Bellfleur Kitaika, Virginia Crab, and Hibernal, with Charlamoff, Anis, Kulon Kitaika, and Antonovka Shafran considered good and Rogers McIntosh fair.

The only variety of the lot to show any definite sign of incompatibility with the Rogers strain of McIntosh is Tayezhnoie. It is not known how this particular trunk-former may react with other McIntosh strains. That an incompatible strain may occasionally be encountered is strongly suggested by the report of Tukey and Brase (21), who concluded that the strain of McIntosh used by them was not compatible with Virginia Crab. The possibility should not be overlooked that a strain difference in Virginia Crab also may have caused the incompatibility. When Rogers McIntosh is budded onto Tayezhnoie, a definite line of cleavage develops at the bud union and little pressure is required to break out the budling. In 1945 a moderate wind broke several such branches on three of the 10 trees of Tayezhnoie. Critical examination revealed that every bud union showed this weakness.

No lack of hardiness to the conditions encountered has been seen in any of these trunk-formers during the 5 years that they have been under test in Maine.

All these trunk-formers except Charlamoff and Rogers McIntosh were included by Bradford (4) in his study of the nursery behavior of the European varieties in comparison with Virginia Crab as the standard American trunk-forming stock. In the first nursery year a larger percentage of Virginia Crab trees reached buddable size (6 mm diameter at 76 cm height) than of Anis, Antonovka Shafran, Bellfleur Kitaika, Hibernal, Kulon Kitaika, or Tayezhnoie. Bradford foresaw, however, the likelihood that in the second year and later years, as required for branch budding, the varietal growth relationships might change materially.

Maine growers who are experimenting with trunk-formers demand for the purpose a variety that will make vigorous growth during the early formative years. Slow-starting varieties appear at a disadvantage where planted along with standard commercial trees of varieties that exhibit more initial vigor. On this account particular attention was given in this study to the time required to complete the top-working of the several varieties.

Table IV shows the percentage of the budding that was done in the first year and the cumulative percentage for the second and third years. The ability of some varieties to make vigorous growth early in the

TABLE IV—CUMULATIVE PERCENTAGE OF BUDDING DONE DURING THE FIRST 3 YEARS OF TOP-WORKING NINE TRUNK-FORMING STOCKS

Variety	Percentage of Budding Done by			Total Number of Buds*
	1942	1943	1944	
Anis	6.7	25.6	66.1	74
Antonovka Shafran	26.0	53.4	86.2	73
Bellfleur Kitaika	8.2	26.0	73.9	73
Charlamoff	27.8	54.0	85.1	61
Hibernal	10.2	30.5	61.0	55
Kulon Kitaika	16.1	43.5	82.2	62
McIntosh	0	3.9	45.1	51
Tayezhnoie	9.5	33.3	76.1	84
Virginia Crab	13.5	41.6	73.0	89

*This includes the final budding of 1945.

life of the tree is shown by the relatively high percentage of budding that was done the first year with some varieties, particularly Antonovka Shafran, Charlamoff, and Virginia Crab. Some slow-starting varieties, such as Bellfleur Kitaika and Tayezhnoie, seem to grow quickly once they start, and by the end of the third year the cumulative percentage of budding is about the same as with the varieties that start more vigorously. From the viewpoint of a commercial orchardist using trunk-forming stocks, a variety that develops fast enough to permit over 25 per cent of the budding to be done the second year after planting and requires only a small amount of budding to be done as late as the fourth year may well prove to be the best variety to use. However, subsequent yield data may yet show a more slowly-starting variety to outyield all others and thus to be more desirable in that respect as a trunk-former.

The total number of buds inserted in each tree shows that Virginia Crab and Tayezhnoie exhibit a growth characteristic that makes the selection of branches to be top-worked somewhat difficult. An average of 8.9 buds per tree were inserted in Virginia Crab whereas actually perhaps only five or six top-worked branches are needed to produce a good orchard tree. Some of this "extra" budding may have been due to indecision on the part of those doing the work, but it more likely is due to the presence of an overabundance of branches all of which looked as though they might be desirable in the top-worked tree. Undoubtedly, some judicious pruning will be required in subsequent years to remove these excess branches. From the viewpoint of establishing a commercial orchard on trunk-forming stocks, this characteristic may be undesirable since inexperienced orchardists doing their own top-working may insert too many buds. But from the viewpoint that it widens the opportunity for branch selection, such a characteristic may well prove desirable. If somewhat more than a minimum number of branches are budded, an occasional bud failure might become negligible since the "extra" branches budded would act as an insurance against loss of bearing area from such bud failure.

The data presented in Table IV are rearranged somewhat in Table V. Here the varieties are rated during the second and third years of top-working, with Virginia Crab taken as the standard. In 1943 four varieties were rated higher than Virginia Crab, and in 1944 five varie-

TABLE V—COMPARATIVE RATING OF VARIOUS TRUNK-FORMING STOCKS DURING TWO OF THE YEARS REQUIRED FOR TOP-WORKING

Rating in 1943		Rating in 1944	
Variety	Percentage	Variety	Percentage
Charlamoff	129.8	Antonovka Shafran	118.1
Antonovka Shafran	128.4	Charlamoff	116.6
Kulon Kitaika	104.5	Kulon Kitaika	112.6
Virginia Crab	100.0	Tayezhnoie	104.2
Tayezhnoie	80.1	Bellfleur Kitaika	101.2
Hibernal	73.3	Virginia Crab	100.0
Bellfleur Kitaika	62.5	Anis	90.5
Anis	61.5	Hibernal	83.6
McIntosh	9.4	McIntosh	61.8

ties. The recognized tendency for Hibernal to be slower than Virginia Crab in starting out as an orchard tree is also illustrated here.

As pointed out earlier in this report, an evaluation of trunk-formers as stocks for standard commercial apple varieties should take into consideration the orchard endurance and the total production of fruit over a period of years. Maney (13) has expressed a preference for Virginia Crab because in a comparison of this variety with Hibernal he found that with Virginia Crab as the trunk-former some varieties grown in Iowa produced not only more fruit but also a greater percentage of fruit of high quality. On the other hand Clark (5) has stated that in commercial orchard practice in Iowa he prefers Hibernal to Virginia Crab because of its greater hardiness. Charlamoff is in disfavor in Canada as reported by Blair (3), the reason given being a tendency for the branches of the trunk-former to break under a load of fruit. On the basis of comparisons herein reported on eight trunk-forming stocks, it would seem that, of the eight, Antonovka Shafran, Charlamoff, Kulon Kitaika, and Bellfleur Kitaika deserve further testing as to their potential value as trunk-formers in regions where winter injury limits apple production.

Reciprocal Influence of Stock and Scion with Respect to Hardiness:—There are but few data to show that the rootstock will measurably influence the hardiness of the scion worked upon it. Blair (2) found that various clonal and seedling rootstocks had no effect upon the hardiness of the scion varieties. On the other hand, Kuroshunov (12) stated that European Mountain Ash was an ideal dwarfing stock for pears since in addition to other desirable characteristics there was a tendency for it to increase the hardiness of young seedlings grafted upon it. Evidence is gradually accumulating to show that the scion will appreciably influence the hardiness of the root, but it is impossible to predict the trend of the influence as hardy scions may reduce the hardiness of the rootstock. Stuart (19) found that the tenderest roots were those produced under Wealthy which was the hardiest of the four scion varieties used. Filewicz and Modlibowska (7) noted that Antonovka, although very hardy, would decrease the hardiness of Malling IX and some seedling rootstocks. When Cox Orange Pippin, a tender variety, was budded onto Malling IX, 14 per cent of the rootstocks were subsequently injured by freezing, whereas when Antonovka was budded onto the same stock, 81 per cent of the rootstocks were injured.

Evidence is gradually accumulating also to show that there is a reciprocal influence between the intermediate stock and the scion, with respect to hardiness. Again it is impossible to predict the trend of this influence or even to predict whether any influence will occur. Schmidt (18) found that when a tender variety like Belle de Boskoop was the intermediate stock it winterkilled even when top-worked to hardier varieties. Waring and Hilborn (22) reported that Baldwin top-worked to McIntosh withstood the severe winter of 1933–34. Gogvadze (9) found that lemons on tangerine stocks were uninjured in the severe winter of 1939–40 in Russia when both lemon and tangerine trees not top-worked were severely injured. Passy (16) recently noted in

France that when a hardier species of Cotoneaster was grafted into the branches of a less hardy species, the latter became as hardy as the scion varieties. Branches on the same stock not top-worked were winterkilled. Edgecombe (6) noted after the November, 1940, freeze that there was less injury to the twigs of Jonathan, Turley, and Stayman when these varieties were top-worked on Hibernal. However, Hilborn (10) found that Baldwin winterkilled when top-worked on Hibernal while adjacent trees of Baldwin on Virginia were relatively uninjured. The winter of 1940–41 was severe enough to injure Baldwin trees at Orono. Single-worked trees were completely killed regardless of the kind of rootstock. There was somewhat less injury to trees propagated on Malling I but these trees were weak in the 1941

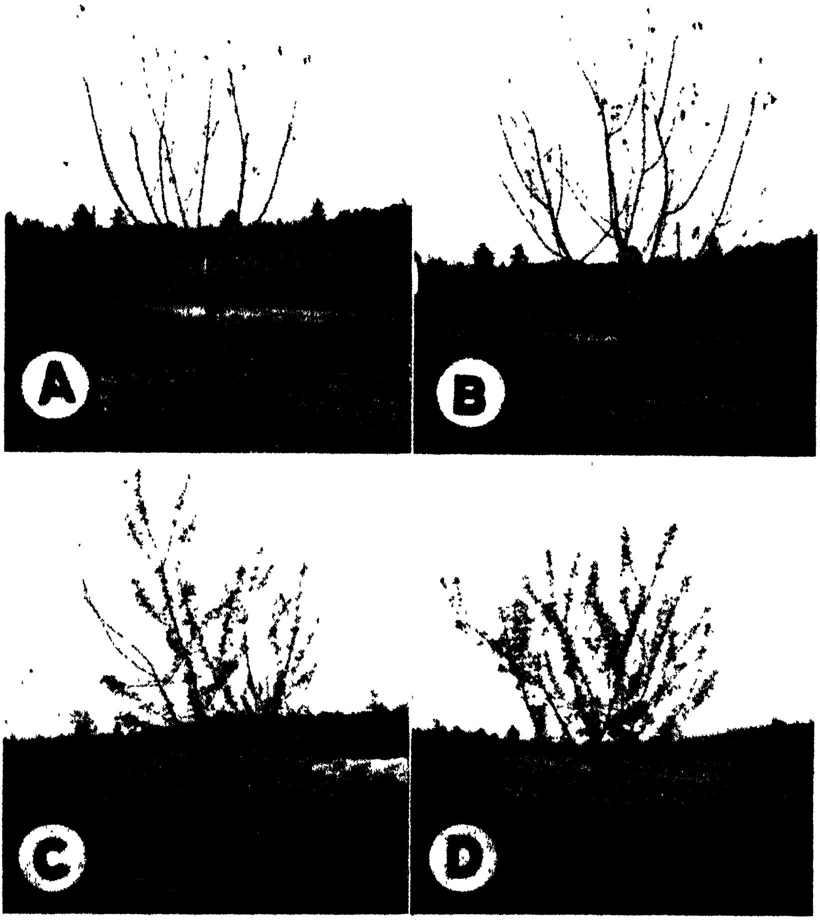

FIG. 3. Baldwin trees at Orono. A and B are single worked trees. In A the rootstock is Malling II and in B the rootstock is Malling XIII. C and D are double worked trees. In C the intermediate stock is Hibernal and in D the intermediate stock is Virginia.

growing season and died the following year. Fig. 3 shows the severity of the injury on Malling II and XIII. Fig. 3, C shows the injury to Baldwin when top-worked on Hibernal. One branch is completely killed and the remaining branches are injured. Weak foliage was produced on this tree in the spring of 1941 and by midsummer all the Baldwin wood was dead on all of the trees of this stock-scion combination. The injury extended just to the graft union; there was no injury to the Hibernal wood. It appeared at first that some of the Baldwin wood for a distance of 12 to 18 inches from the graft union was relatively uninjured, but by midsummer this wood was dead. In Fig. 3, D illustrates the hardiness of Baldwin when top-worked on Virginia. The only injury to this stock-scion combination was a slight amount of blackheart in the pith of the terminal growth of 1940, and this injury had no effect upon the vigor and growth of the trees from 1941 to date. It is generally recognized that Hibernal is hardier than Virginia but in this comparison Hibernal did not exhibit any transmission of hardiness to the Baldwin scions whereas Virginia apparently did transmit a considerable degree of hardiness. There was no appreciable difference in either growth or yield between any of the top-worked trees, regardless of the kind of trunk-former, previous to the time of the injury.

Edgecombe (6) noted after the November, 1940, freeze that there was less injury to the twigs of Jonathan, Turley, and Stayman when these varieties were top-worked on Hibernal than when grown on seedling roots. Laboratory studies on the reciprocal effect of stock and scion with respect to hardiness are far from complete but some preliminary data are given in Table VI. All the combinations listed in this table had domestic seedling rootstocks. However, some of the trees also had an intermediate stock of either Hibernal or Virginia. Specific conductivity determinations were made on artificially frozen material following the method used by Stuart (19). Determinations were made in this case only on the scion variety. The data show that Virginia as an intermediate has influenced considerably the hardiness of both Baldwin and Cortland, but has had no effect on McIntosh.

TABLE VI—RELATIVE HARDINESS OF THREE SCION VARIETIES ON SEEDLING ROOTSTOCKS AND INTERSTOCKS AS DETERMINED BY ELECTRICAL CONDUCTIVITY AFTER ARTIFICIAL FREEZING

Stock	Scion Variety (Specific Cond. × 10^{-6})		
	Baldwin	Cortland	McIntosh
Seedling	460	441	322
Hibernal	445	417	310
Virginia	371	349	315

Difference required for significance at 1 per cent level = 65.2, greater hardiness being indicated by smaller values.

This transmission of hardiness by the use of Virginia as an intermediate has been demonstrated in an orchard venture at Patten in northeastern Maine, near Mt. Katahdin, where the usual winter temperatures reaches an extreme of —45 degrees F. Here over 1,000 trees were planted of which half were Virginia and the others were single-worked nursery trees of commercial apple varieties. Topworking was begun on the Virginia trees in the second orchard season, and in the fourth orchard season most of the single-worked trees were so severely injured that they were removed and replaced with various trunk-formers. Table VII shows the injury that occurred in this planting. The only Virginia trees that were injured were a few young replants that had grown vigorously the previous season and did not mature sufficiently. Only a few cases of slight injury were found in top-worked trees on Virginia and this injury was confined to the pith of the young wood. In 1944 this planting was beginning its seventh growing season and even such relatively non-hardy varieties as Baldwin, Spy, and Red Gravenstein are making excellent growth and showing little or no winter injury where Virginia is the trunk-former.

TABLE VII—PERCENTAGE OF YOUNG APPLE TREES WINTER-INJURED IN THE WOODMAN POTATO COMPANY ORCHARD AT PATTEN

Vareity	Percentage Injured
Baldwin	100.0
Early McIntosh	100.0
Yellow Transparent	100.0
Spy	97.8
Cortland	87.1
Red Gravenstein	80.0
McIntosh	78.2
Wealthy	25.0
Virginia Crab	2.9

Rootstock Studies:—Some attention has been given to the Malling rootstocks, although they had not proved promising with respect to hardiness. Malling I, II, IV, IX, XIII, and XVI have been under observation for several years and all have been of doubtful hardiness in the nursery. A few other clonal rootstocks have been studied in Maine enough to warrant tentative appraisal. Vermont 316, 317, and 323 seem to be hardy enough under Maine conditions. Spy 1283, 1263, 1256, and 227–2, and Briar Sweet x Mercier 1225 and 1223 are apparently not hardy enough to warrant much consideration in Maine. Recently more emphasis has been given to Manchurian Crab (*Pyrus baccata* var. *mandschurica*), using the Harbin selection made by Hansen. This seedling rootstock is reported to be very hardy and to have a semi-dwarfing effect on the scion varieties. Nursery trials in Maine show it to be well adapted to Virginia. Compared with performance on domestic seedlings, the bud take on Harbin was higher and the resulting Virginia Crab trees were larger and better branched as one-year nursery trees. There is, however, one principal disadvantage in using Manchurian Crab as a rootstock. The bud union is brittle and easily broken even during the second year in the nursery. This brittleness also extends into the root system and greater care must be exercised when these trees are dug.

SUMMARY

A preliminary evaluation of 25 potential trunk-forming stocks indicates a few instances of incompatibility that eliminate certain stock-scion combinations from further consideration. Both Gravenstein and Red Gravenstein show some incompatibility with Virginia Crab. Rogers McIntosh is definitely incompatible with Tayezhnoie.

Comparisons of eight trunk-formers when top-worked to Rogers McIntosh indicate that Antonovka Shafran, Charlamoff, Kulon Kitaika, and Bellfleur Kitaika show promise and deserve further study.

That there is a reciprocal influence with respect to hardiness in various stock-scion combinations is indicated. Baldwin on Virginia Crab appears quite hardy, whereas Baldwin on Hibernal shows considerable tenderness. Specific conductivity determinations after artificial freezing indicate that the hardiness of some varieties may be increased when Virginia Crab is used as a trunk-former.

Brief experience with various rootstocks tends to show some promise in using the Harbin selection of *Pyrus baccata* var. *mandschurica* as a rootstock for some trunk-formers, although a brittleness at the bud union may finally result in lack of favor for this particular rootstock.

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The Anchorage of Clonal Stock Apple Trees[1]

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It is recognized that poor anchorage is one of the weaknesses of dwarf and semi-dwarf trees. The hurricane of September, 1944, offered an opportunity for observing the injury from severe winds on a 6-year-old orchard of many varieties on various clonal stocks. The orchard was growing in sod on a site open to the north wind of the hurricane. The injury was of two kinds: (1) breakage of the union or, in some cases, below the union, never above the union, (2) tipping, varying from slight to enough to ruin the tree. Shortly after the hurricane, a survey of the wind injury was made and the results are shown in Table I. The number of trees in each combination or rootstock and scion was either eight or nine. It will be seen that from none to more than half of the trees were ruined, varying with the combination. Trees on M V, X, XII, XIII, XV, and XVI were represented in the orchard by the same number of trees, but none of them were tipped or broken. Three varieties on seedling rootstocks showed no injury.

Table I shows the amount of injury to the various stion groups. In column 1 of each group of four is shown the number of trees broken at

TABLE I—HURRICANE INJURY ON CLONAL STOCK TREES IN A TOTAL OF EIGHT OR NINE TREES, SEPTEMBER, 1944

Variety	Malling I				Malling II				Malling III				Malling IV			
	Bro*		Tip**		Bro*		Tip**		Bro*		Tip**		Bro*		Tip**	
	At†	Be‡	L§	M††	At†	Be‡	L§	M††	At†	Be‡	L§	M††	At†	Be‡	L§	M††
Baldwin.					0	0	0	0	0	0	0	0	3	0	2	0
Gallia					0	0	1	0					1	0	2	1
Golden Delicious..	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	1
Kendall	0	0	0	0	0	0	0	0					0	0	1	1
McIntosh ...	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	2
Oldenburg	0	0	0	0												
Red Gravenstein	2	0	0	0									5	1	0	0
Red Spy	0	0	0	0	0	0	1	0	2	0	2	0	0	0	1	0
R.I. Greening	0	0	0	0					0	0	0	0				
R.I. Greening	0	0	0	1												
Starking					0	0	1	0	0	0	0	0	0	0	1	1
Wagener	0	0	0	0												
Webster					0	0	0	0								
Davenport 25													2	0	2	1
Diadem													1	0	1	2
Edgar													1	0	4	0
Hume													1	1	3	3
Linda													4	0	1	0
Macoun													3	0	3	0
Macross													3	0	1	0
Melba													0	0	0	0
Van Buren	0	1	0	0												

*Bro = broken over.
**Tip = tipped more or less.
†At = at the union.
‡Be = below the union.
§L = little, less than 45°.
††M = much, more than 45°.

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[1] Contribution No. 596 of the Massachusetts Agricultural Experiment Station.

the union; column 2, those broken below the union; column 3, those tipped less than 45 degrees; and in column 4, the number tipped more than 45 degrees. Thus, columns 1, 2, and 4 represent the numbers seriously damaged or totally ruined, while column 3 represents trees little injured which could be straightened readily. There were no trees of the combinations represented by the blank spaces. No trees on Malling V, X, XII, XIII, XV, and XVI were damaged.

It seems safe to conclude that trees on M IV suffered more than those on other rootstocks. The breakage and tipping of these trees indicates a serious weakness of this rootstock.

There were in this orchard trees of three varieties on M IX. These few trees were supported by stakes. While the stakes did not entirely prevent injury, they probably saved many trees. In another 2-year-old orchard of 256 trees of 16 varieties on M IX, many trees were badly tipped and a few broken. The great weakness of trees on M IX is in the brittleness of the wood of this rootstock, but a small root system giving poor anchorage is partly to blame.

In the summer of 1945 this orchard suffered further from severe winds. In October a count was made of the trees missing from wind injury. The results are shown in Table II.

TABLE II—NUMBERS OF MISSING TREES IN 1945

Malling Stock	Total Trees	Per cent Missing
I	105	4
II	59	3
III	74	3
IV	156	32
VIII	4	25
IX	48	29

These figures again suggest that M IV and IX (and possibly VIII) are the worst offenders. Trees on M IX are recommended only for backyard trees, and in such locations they stand up quite well. Probably they have more protection than the trees in the exposed orchard here considered. A survey of cooperative clonal stock orchards over the state in the fall of 1945 in which many of the same stion combinations had been planted showed much less wind injury, but it was of much the same type. Trees on M IV showed most frequent injury.

Trees on M IV are a doubtful proposition for some varieties in commercial orchards unless for sheltered sites. Varieties that suffered most are Baldwin, Hume, Linda, Macoun, Macross, and Red Gravenstein. Probably the old Gravenstein would behave in the same way and should not be budded on M IV. Melba and Red Spy are the only varieties on this rootstock that have escaped damage.

The fact that so many trees broke at the union suggested a study of the external evidence of irregularities at this point. When these trees were younger, measurements of trunk diameter above, at, and below the union showed little or no consistency (1). In the fall of 1944, each tree was given a rating from 0 to 5. The union was rated 0 if there was slight or no external evidence of the union and up to 5 as evidence of irregularities increased. The trees are randomized in the orchard and the rating made in ignorance of the combination of rootstock and variety rated. Ratings were based on (1) external evidence of a distortion of the fibers, (2) size of the bulge at the union, (3) difference in size of the trunk above and below the union; it was always smaller above the union. This was the usual case with all varieties on M IX.

The average rating of each combination multiplied by 100 is shown in Table III. These figures should be taken with much salt, but it is thought that they do warrant some tentative conclusions. Three lots of a total of 25 seedling rooted trees rated 160. If this figure can be relied on, all the standard and near standard stocks (including M I) cause less or only a little more irregularity at the union than seedling rootstocks; while II, III, IV, V, and IX cause distinctly more irregularity. We have noticed that the characteristics of the unions of a variety are more variable on seedling rootstocks than on clonal rootstocks.

TABLE III—RATINGS OF STION UNIONS

Variety	Rootstock									
	I	II	III	IV	V	IX	XII	XIII	XV	XVI
Baldwin		238	325	260			78	100	167	
Davenport 25				363						
Diadem				356						
Edgar				278						
Gallia		200		422						
Golden Delicious	133	150	337	143	278	375				100
Hume				313						
Kendall	133	211	275	311	278					
Linda				229						
Macoun				314						
Macross				300						
McIntosh	100	178	250	289	178		56	100	189	75
Melba				267						
Oldenburg	167				322					187
Red Gravenstein	200		262	433	400					
Red Spy	144	233	337	289	178	462				37
R. I. Greening	220				378					150
Starking		156	275	300		462	122	200	167	
Van Buren	125									
Wagener	100				189					166
Webster		222								
Average	147	199	294	304	275	433	85	133	174	119

We may also conclude that M IV and IX are more uncongenial than M II and V. The irregularity of unions with M IV and IX are quite different. Trees on M IV show a bulge at the union and the broken trees show that the fibers are arranged concentrically and not in the normal longitudinal fashion; hence, the weakness (Fig. 1). With trees on M IX, the irregularity is due to a much greater cross diameter of the stock though there is often some signs of an irregularity in the fiber arrangement.

In general, the rating increases with increased dwarfing power of the rootstock though with M IV the rating is higher than its moderate dwarfing effect would suggest. The fact that trees on M V were not injured suggests that it may be valuable as a semi-dwarfing rootstock, but experience indicates that it has other shortcomings and it is not recommened by those having experience with semi-dwarfing root-

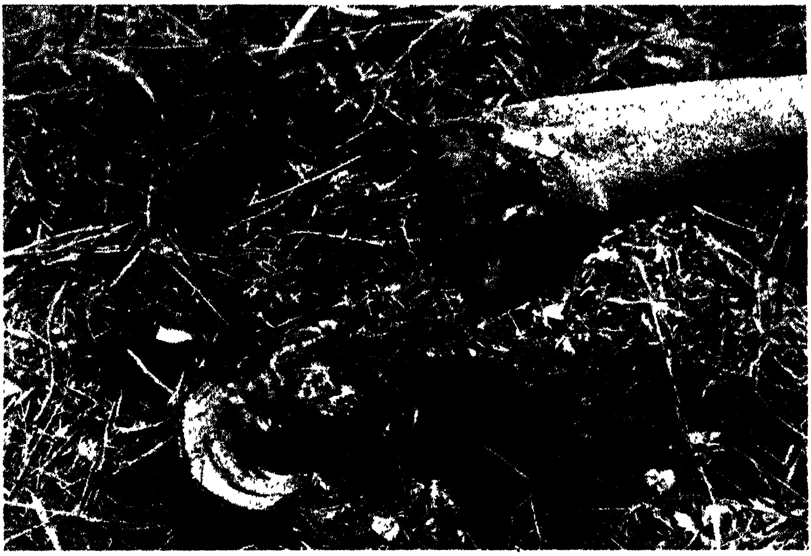

FIG. 1. Red Gravenstein on Malling IV—a smooth break at the union.

FIG. 2. Macross on Malling IV—a rough break at the union.

stocks. M III suffered rather badly and this rootstock sends out many suckers which are a nuisance. There is little data regarding M VI and VIII. This leaves M I and II as the semi-dwarfing stocks most promising at present.

This unfortunate experience brings out the most serious weakness of dwarf and semi-dwarf trees. Such high winds as those which did so much damage in Massachusetts in September of 1938 and 1944 are unusual; yet they have occurred and will recur in occasional years in the future. We do not feel that semi-dwarf trees for commercial orchards are entirely discredited. Some suggestions may be made of practices that will minimize the danger of wind injury.

1. Avoid certain uncongenial stion combinations. We need more information on this. A few suggestions have been made in this paper.

2. Select trees with a strong well-balanced root system. Clonal-rooted trees seem to be more likely to have one-sided or ill-balanced root systems than seedling-rooted trees.

3. Plant only on deep, rather fertile, well-aerated soils that offer favorable conditions for strong root development.

4. Avoid open wind-swept sites.

5. It is possible that deeper planting would favor firmer anchorage. This would involve high budding in the nursery for scion rooting must be prevented if the dwarf stature is to be preserved.

6. Form the head somewhat lower than is customary with seedling-rooted trees. The orchard trees here discussed have rather high heads and high winds can do more injury than on lower-budded trees. Trees on M IX should be grown as bushes rather than trees.

7. The dwarfing effect of the root can be made more effective by pruning the top. We believe that the harmful effects of severe top pruning will be less than on more vigorous seedling-rooted trees.

8. While we believe that these suggestions will be effective in minimizing wind injury, it may be necessary in some cases to provide support. Discarded iron piping ¾ to 1½ inch in diameter cut about 4 feet long has been found satisfactory. Such support may be impracticable in commercial orchards but may be used for home garden trees, especially when on M IX, planted on exposed sites.

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1. SHAW, J. K. Trunk diameters of young apple trees on clonal stocks. *Proc. Amer. Soc. Hort Sci.* 40:269–271. 1942.

The Influence of Malling Clonal Rootstocks on the Growth of Certain Apple Varieties[1]

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THE interrelation of rootstock and scion in apples has been studied at this Station since 1912. The first orchard was planted in 1916. The rootstocks used were some of the common orchard varieties. They were propagated by the nurse-root method (3), and the rooted scion budded to desired varieties. This orchard was maintained for about 20 years when the trees were removed. Experimental results were meager. It was hoped that this would prove a means of getting more uniform orchard trees, but results indicated that there was little or no reduction in variability of growth and production when a variety was grown on uniform rootstocks (1).

Meanwhile, the clonal rootstocks grown in Europe had been investigated and pure true-to-name types made available. In 1924, 13 Malling types were imported and have since been propagated and studied (7). Numerous varieties have been budded on them and grown in our orchards and in others about the state. The first orchard was planted in 1928. It contained about 275 trees of McIntosh and Wealthy on many of the Malling rootstocks. The results from this orchard have been reported (4, 10, 11). Most of the Wealthy and nearly half of the McIntosh trees were removed in 1939 on account of crowding. The size of the remaining trees in 1945 is given in Table I.

TABLE I—TRUNK DIAMETER OF MCINTOSH ON SEVEN MALLING ROOTSTOCKS AT 18 YEARS

Variety	Diameter of Rootstock (Mm)						
	I	IV	V	VI	X	XIII	XVI
McIntosh	223	233	213	227	256	240	270

The size of the trees maintains much the same order as in 1938 (11). The fact that Wealthy on M I behaves as a very dwarf tree has been confirmed by the behavior of trees of a later budding. McIntosh on M XVI has outyielded those on the other six stocks in recent years by about 50 per cent, supporting our belief that M XVI is a good rootstock for standard or near standard McIntosh trees. Of course, semi-dwarf trees could be maintained with more trees per acre and acre yields might equal or exceed that of trees on M XVI. Trees on M X and M XIII require nearly as much space as those on M XVI.

Other investigations have indicated that the various types of flowering crabs show great differences in their behavior on the Malling rootstocks (5, 9). Some fail entirely on certain rootstocks while others succeed very well. Malling XII seems to be especially compatible with most flowering crabs.

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[1] Contribution No. 595 of the Massachusetts Agricultural Experiment Station.

Between 1932 and 1936 considerable numbers of the various Malling stocks were propagated and the trees planted in orchards on our own land and at various places over the state. The growth of these trees will now be considered.

EXPERIMENT STATION ORCHARD B

This orchard of 900 trees of various varieties on several clonal stocks and a few on seedling stocks was set in early May, 1939. The site was one from which another orchard had been removed 2 years before. The soil was not very fertile. It was low in potassium, but this was readily corrected by applying potash to the young trees. This treatment brought out a magnesium deficiency which has been partially corrected by magnesium treatments. The rather marginal soil condition has perhaps favored variation among the trees which is one of the most marked results observed; yet the trees have grown rather well. The orchard was kept in sod with strip cultivation along the rows for the first 3 or 4 years. The grass strips have been fertilized with a 1–1–1 fertilizer so that the growth of grass has gradually improved. It was cut and spread around the young trees until 1945 when it was cut and allowed to lie in place. Some additional mulch has been brought in, especially where the growth was poor.

The orchard is considered to be in two parts, one of nine plots of 49 trees each and the other of eight plots of 20 trees each. All plots are separated by guard rows which accounts for the other 299 trees. The plot arrangement was used with the idea of superimposing some sort of a nutrition experiment. Thus far, this has been a study of the magnesium deficiency which developed in the early years of the orchard. The trees on the plots were randomized and each guard row is of some one variety on two or more rootstocks planted alternately.

The original plan to treat the results statistically has been ruined principally by two unfortunate circumstances. Most of the trees were propagated in our own nurseries on rootstocks from our own stock bed. Four varieties were purchased from a nursery. These were supposed to be on M IX, but in a few years it was discovered that they were on M 1. The early years of the orchard were characterized by hurricanes and near hurricanes which destroyed many trees. This is discussed in another paper in this Volume.

GROWTH

All the trees in the orchard have been measured annually by taking the trunk diameter 15–18 inches above the union and, in later years, by taking the trunk circumference at the same place. All measurements have been converted into trunk cross-sectional area and reported in square centimeters.

The trunk size of the various stions after the second to seventh season are shown in Table II. It is evident that M IX and doubtless M VIII are in a class by themselves, all varieties being much smaller than when grown on other rootstocks. It must be noted that trees on these stocks blossom and bear very early and fruiting is a potent dwarfing influence. The semi-dwarfing and more vigorous rootstocks

TABLE II—ORCHARD B. TRUNK CROSS-SECTIONAL AREA AND BLOOM

Root-Stock	Average Trunk C-S Area (Cm^2)						Average Bloom (Per Cent)			
	1940	1941	1942	1943	1944	1945	1942	1943	1944	1945
Golden Delicious										
I	2	4	9	17	32	52	1	3	2	28
III	2	5	9	13	25	33	18	31	4	74
IV	3	6	12	21	47	59	8	5	5	26
V	2	4	8	14	27	40	1	6	3	7
V	2	4	8	15	31	48	1	1	5	15
VIII	2	3	5	7	10	11	60	25	18	79
IX	3	4	6	8	12	14	51	26	20	79
IX	2	4	6	8	13	16	53	20	20	71
XII	4	8	16	29	58	86	0	0	3	4
XVI	3	7	14	30	50	75	1	1	4	2
A	3	6	13	24	49	76	0	0	0	1
C	3	6	13	24	49	76	0	3	3	13
Baldwin										
II	4	8	17	28	54	75	3	3	2	3
III	3	8	13	26	43	61	28	1	3	8
IV	3	7	15	26	48	58	2	2	2	12
X	4	9	20	33	60	84	0	0	0	0
XII	3	8	18	34	63	91	0	0	0	0
XIII	3	6	12	24	44	62	0	0	0	0
XV	3	8	13	23	43	63	0	0	0	0
A	3	8	17	26	48	68	0	0	0	1
C	7	13	36	51	85	115	0	0	6	1
323	4	8	11	29	51	71	0	1	2	1
Kendall										
I	3	6	12	21	32	60	0	1	3	14
II	4	7	13	25	46	68	4	1	14	18
III	2	4	8	16	30	43	4	4	2	22
IV	3	6	12	22	43	60	1	0	2	8
V	3	6	11	18	34	49	0	0	1	10
XIII	3	7	13	25	48	73	0	0	0	0
XV	2	5	11	20	39	62	0	0	0	0
McIntosh										
I	2	4	11	21	44	68	0	2	2	8
I	3	6	14	27	48	72	1	9	4	24
II	2	5	12	20	41	63	4	7	4	20
III	3	6	13	21	40	56	2	11	1	55
IV	2	4	10	17	29	39	2	6	12	41
V	2	5	10	19	39	60	0	2	4	10
XII	3	6	13	26	50	77	0	0	1	1
XIII	3	6	15	26	49	74	0	2	1	2
XV	2	5	10	18	35	52	0	1	1	2
XVI	3	8	19	34	59	87	0	0	2	1
C	3	6	11	21	39	68	0	0	1	4
323	3	7	14	24	44	67	0	1	2	5
Red Gravenstein										
I	4	9	20	35	64	98	1	2	4	15
III	3	8	18	31	59	77	11	7	9	43
IV	3	8	16	28	51	57	11	3	15	52
V	7	13	25	39	69	96	3	4	13	14
XVI	6	14	28	43	79	115	0	1	38	5
Seedling	2	4	10	18	40	53	0	20	1	2
Red Spy										
I	1	2	5	11	24	40	0	0	0	0
II	4	8	13	21	39	56	1	0	0	1
III	3	5	9	14	26	37	3	7	4	2
IV	3	5	10	16	31	44	0	0	0	1
V	3	5	10	16	32	51	0	0	0	0
IX	2	3	6	9	12	12	6	5	8	40
XVI	4	8	17	29	52	75	0	0	0	0

TABLE II—*(Concluded)*

Root-Stock	Average Trunk C-S Area (Cm)						Average Bloom (Per Cent)			
	1940	1941	1942	1943	1944	1945	1942	1943	1944	1945
Starking										
II	3	5	9	17	35	53	1	3	6	22
III	3	5	10	18	30	41	11	9	28	28
IV	2	4	8	13	24	34	1	10	13	29
IX	2	3	5	6	9	11	60	16	50	48
X	3	8	16	30	55	83	8	39	21	5
XII	3	6	11	20	40	62	8	9	2	6
XIII	2	3	7	12	23	34	20	24	36	29
XV	3	4	8	13	27	42	1	21	4	6
A	2	4	9	16	34	51	2	10	3	2
C	3	6	11	20	42	63	1	7	2	9
R. I. Greening										
I	2	6	12	23	49	77	0	14	1	12
I	3	8	19	36	71	99	2	22	12	35
V	3	8	16	27	57	85	1	6	5	17
XVI	4	9	23	42	83	118	6	2	8	1
Wagener										
I	2	6	11	19	36	53	5	4	1	18
I	3	7	12	19	31	44	8	3	2	36
V	3	5	8	13	27	38	0	6	3	20
XVI	3	5	9	15	29	43	0	2	1	4
Oldenburg										
I	2	4	7	12	23	37	27	0	1	36
V	3	5	8	14	25	36	25	0	43	58
XVI	3	7	12	20	36	52	37	0	1	14
Diadem										
IV	3	6	9	15	29	42	13	4	16	39
V	3	7	12	18	32	44	2	3	2	32
*Davey**										
IV	2	5	10	17	33	46	5	8	8	61
XVI	1	4	10	20	40	65	2	1	1	1

*Davey is a new variety; formerly designated as Davenport 25.

produce larger trees by the measure here used, but there are only doubtful differences between the different rootstocks. Trees on the more vigorous rootstocks (X–XVI inclusive) are generally larger and possibly those on M III are smaller than those on other semi-dwarfing rootstocks.

It is evident that the relative vigor of varieties appears in trees grown on these rootstocks. Baldwin, Red Gravenstein, and R. I. Greening make relatively large trees, while Red Spy makes smaller trees as they do on the usual seedling stocks. When we raise the question whether a given rootstock dwarfs all varieties equally, the answer is not clear. The effect of M I on McIntosh and Wealthy is one definite case. Our studies and observations show so potent an influence of environmental, chiefly soil, differences that we hesitate to draw conclusions. Computations of the standard error show that rather large differences are not statistically significant. The growth of Starking shown in this table is to be taken with reservations for reasons given later in this paper.

FRUITING AGE

One of the principal arguments for dwarfing rootstock is the well-known characteristic of earliness of coming into bearing. Individual tree production records of this orchard have been taken, but as the crops of both 1944 and 1945 were greatly and irregularly reduced by spring frosts, it is felt that bloom records give a better indication of potential earliness of bearing. It has been our practice to estimate for each tree the percentage of growing points that have blossom clusters. This may be a rather crude way of determining bloom, but it certainly gives some indication of potential earliness of production. Such records have been taken in this orchard beginning in 1942.

There was little bloom or fruiting on any of the trees previous to 1942, the fourth season of growth. Some of the varieties on rootstocks VIII and IX, which naturally come into bearing early, bloomed and fruited in the third year, and we know that such scions often fruit even earlier. The average percentages of bloom for most of the rootstock-scion combinations in this orchard are given in Table II. It is clear that stock effects are more definite on bloom than on trunk cross-sectional area. Malling VIII and IX are in a class by themselves. It is among the semi-dwarfing stocks that stock effects on bloom are most clearly seen. Malling III seems to induce early blooming followed by IV, I, II, and V in order. The standard and near-standard stocks seem to be in about the same class as seedling-rooted trees.

The bearing habits of the several varieties appear in these trees. Golden Delicious bears early, Baldwin later, and Red Spy still later. Early fruiting of Oldenburg and Wagener does not seem to be hastened much by semi-dwarfing stocks. Perhaps it is safe to conclude that varieties that are naturally dwarfish are not so greatly influenced by dwarfing stocks as are more vigorous varieties.

The relatively new variety Kendall is evidently slow in coming into bearing, while Webster bears at an early age.

Comment has been made on the growth of Starking. This abnormal behavior is also seen in the blooming performance. Some of the weak trees bloomed very early, even when on semi-dwarf or vigorous stocks. Other trees have bloomed little but made good growth. The behavior of nine Starking trees on M XIII is given in Table III. Three of the trees have made good growth but have bloomed little. The other six trees bloomed heavily in their early years but have grown little; two

TABLE III—BLOOM AND GROWTH OF STARKING ON M XIII

Tree	Bloom (Per Cent)					Trunk C-S Area (Cm^2)
	1941	1942	1943	1944	1945	1945
C-23	0	0	100	80	100	3
G-3	Many	0	0	0	0	73
G-11	0	80	1	5	100	5
O-7	0	0	0	3	3	87
O-13	Many	Dead	—	—	—	—
O-19	Many	0	40	70	1	9
S-15	0	80	30	90	0	3
W-5	Many	0	Dead	—	—	—
W-21	0	1	0	1	0	55

of them have died. Buds were taken from these vigorous and weak trees and set on Malling XIII stocks. Two-year trees in the nursery are distinctly taller when grown from buds taken from one of these vigorous trees. Other cases of similar behavior of Starking when budded on this and other Malling stocks have been observed. This suggests that possibly some difference is present in our Starking trees (9).

Owen Orchard

A small orchard of 65 trees was planted at Massachusetts State College in 1937. There were two rows of Baldwin, one on M I and XV, the other on M IV and XVI, one row of Golden Delicious on M V and XVI, and one row of Red Spy on M IV and V. In each row the two rootstocks alternated. This orchard was on a more fertile soil and the trees have been cultivated with a cover crop. These conditions have favored growth and checked fruiting. The growth of these trees is shown in Table IV.

TABLE IV—Owen Orchard. Trunk-Cross Sectional Area (cm^2)

Variety	Root-Stock	1937	1938	1939	1940	1941	1942	1943	1944	1945
Baldwin . .	I	3	9	23	37	62	90	106	Record Not Taken	195
	IV	5	12	23	36	59	81	106		150
	XV	6	12	23	37	64	91	122		184
	XVI	3	8	17	29	54	83	117		195
Golden Delicious.	V	2	6	14	21	37	56	76		124
	XVI	2	6	16	23	41	63	88		151
Red Spy	IV	3	6	14	24	44	65	87		141
	V	2	4	10	15	31	50	67		120

In the case of Baldwin, there are no significant differences in present size of the trunks except that those on M IV may be smaller than the others. Golden Delicious on M XVI has gained steadily over those on M V. Red Spy on M IV and M V are not significantly different. Those on M V are in two different rows. Those in one row now average 138 cm^2, while those in the other average only 89 cm^2; the latter are on a wetter soil and may have been poorer trees when set. It is another example of how soil or other environmental conditions can affect the growth of trees.

The trees began to crop in 1942 as shown in Table V. Neither Baldwin nor Golden Delicious have shown much signs of earlier fruiting on the semi-dwarfing rootstocks. Red Spy fruited a little in 1941, then skipped two years, then started into production. The two rows on M V behaved differently. The poorer trees which grew less have not fruited, while both the better rows on M IV and M V have begun to produce.

Gay Orchard

Several cooperative orchards have been planted by fruit growers. These orchards have been watched by staff members and the trees measured annually as a rule. No adequate records of production are available. Some have given helpful information and others have been

TABLE V—OWEN ORCHARD. BLOOM, PER CENT AND YIELD (POUNDS)

Variety	Root-Stock	1941		1942		1943		1944		1945	
		Bloom	Yield	Bloom	Yield	Bloom	Yield	Bloom	Yield	Bloom	Yield
Baldwin......	I	0	0	1	7	9	76	7	80	15	63
	IV	0	0	30	60	2	26	28	76	5	0
	XV	0	0	1	3	3	21	8	6	1	21
	XVI	0	0	1	4	5	27	9	92	1	11
Golden Delicious.......	V	0	0	19	33	7	60	18	115	3	5
	XVI	0	0	7	30	7	86	12	132	5	22
Red Spy	IV	?	6	0	0	0	0	2	7	9	20
(Row B)....	V	?	10	0	0	0	0	1	6	3	11
(Row F) . .	V	?	0	0	0	0	0	0	0	0	0

failures. One of the better ones is in the Town of Palmer. This orchard was planted on new land. It has been managed on a system of sod or rough cultivation and the trees have grown rather well. The growth of the trees is shown in Table VI. McIntosh trees on seedling stocks are larger than on any of the clonal rootstocks. This superiority should be taken with some reservation. First-class 2-year trees were planted, while the other were 1-year trees. McIntosh trees on M III are the smallest; this is a common experience and may be due to earlier fruiting.

TABLE VI—GAY ORCHARD. TRUNK CROSS-SECTIONAL AREA (CM^2)

Variety	Root-stock	No Trees	1937	1938	1939	1940	1941	1942	1943	1944	1945
Early McIntosh	V	5	1	2	3	6	7	11	19	Record Not Taken	24
	XIII	7	2	3	5	10	13	17	26		44
Macoun	V	7	3	5	10	17	22	27	36		57
	XVI	8	2	6	11	19	27	37	52		97
McIntosh	III	15	1	3	5	9	13	19	29		59
	IV	8	2	3	5	10	15	26	38		85
	V	23	2	5	8	13	18	26	38		74
	X	18	3	5	8	13	21	31	47		93
	XIII	12	2	4	8	14	21	30	42		88
	XV	20	2	4	7	14	22	33	49		102
	Seedl.	52	4	13	15	27	40	55	77		141

WALTHAM ORCHARD

A small orchard of four varieties on four semi-dwarf rootstocks was planted at the Waltham Field Station in 1937. The growth of these trees is shown in Table VII. Baldwin on M I has made poor growth, but in other cases, trees on M IV and V have grown more than the same variety on M III. It is doubtful if any differences are significant. Only one of the Macoun trees on M IV remains; the others have been lost by wind damage or mouse girdling.

TRASK ORCHARD

Another cooperative orchard was planted in the Town of Sterling. This orchard is in sod. The trees all grew rather slowly in their early years. (Table VIII) There are two rows of Red Spy nursery-grown trees which have behaved much alike. Both have grown faster than any

TABLE VII—Waltham Dwarf Orchard. Trunk Cross-Sectional Area (cm^2)

Variety	Root-Stock	No. Trees	1937	1938	1939	1940	1941	1942	1943	1944	1945
Baldwin . . .	I	9	3	6	13	19	25	37	52	Record Not Taken	79
	III	8	2	6	11	21	26	43	55		92
Golden Delicious	III	8	3	8	12	20	24	38	50		90
	IV	9	3	8	15	27	34	53	69		104
Starking .	III	7	1	3	6	11	17	28	42		86
	IV	8	2	6	13	24	31	48	60		96
Macoun	IV	3	3	8	18	32	41	72	90		—
	V	4	3	9	19	35	47	70	79		129

TABLE VIII—Trask Orchard. Trunk Cross-Sectional Area (cm^2)

Variety	Root-Stock	No Trees	1937	1938	1939	1940	1941	1942	1943	1944	1945
Baldwin	IV	4	3	6	6	11	19	33	41	Record Not Taken	80
	V	5	2	3	4	7	11	16	21		38
	XII	5	3	4	6	10	17	28	37		45
	XIII	5	3	7	8	13	21	35	47		83
McIntosh	IV	4	2	4	5	8	15	21	31		—
	V	3	1	1	1	2	4	8	10		—
	XII	4	2	3	4	7	13	23	31		66
	XV	3	1	1	1	2	3	6	8		20
Red Spy	II	4	2	3	3	5	7	12	14		25
	III	3	3	5	8	11	18	26	29		49
	IV	11	2	5	5	9	17	26	32		60
	V	5	2	3	4	5	9	15	19		38
	XIII	5	3	5	7	12	20	31	38		69
	XV	4	3	4	4	9	13	19	24		44
	Seedl.	10	1	4	6	10	19	32	42		74
	Seedl.	10	1	4	5	10	19	30	39		76
Kendall	IV	11	2	4	6	9	17	28	36		76
	XIII	10	3	5	7	10	18	30	41		76

of the clonal stock trees during the last 2 or 3 years. Baldwin on M V and M XII, McIntosh on M XV, and Red Spy on M II have grown very slowly. No explanation can be advanced. It is another example of the great effect of soil or other environmental condition on the growth of apple trees.

DISCUSSION

The most significant result of the observations here reported is the differences in growth of any given stion in different orchards. This is doubtless due largely to differences in soil and cultural conditions. It probably is the reason for disagreements which may be found in the many papers which have been published. Naturally, opinions differ as to the degree of dwarfing caused by the various Malling stocks. Maurer (2) gives four groupings and no two are alike. Only a general grouping is suggested here as follows: (VIII, IX) III (VII, V, VI, IV, I) XIII (X, XV) (XVI, XII).

No distinction is made between the varieties in parentheses. The intention is to list them in order of increasing vigor.

M VIII and IX are very dwarfing and of no value in commercial orchards unless it be in very unusual cases. Trees on M III grow as well as any semi-dwarfing stock but show a tendency to come into bearing earlier than do M V and VII inclusive. It suckers from the stock more than the others. M IV forms poor unions with many varieties and shows weak anchorage though it produces rather vigorous early-bearing trees. M V seems to make rather poor producing trees though of good anchorage. M VI shows no outstanding value. We have had little experience with M VII, but it is reported as having promise. This leaves M I and II as the most promising semi-dwarfing rootstocks according to present knowledge. M I acts as a very dwarfing stock when budded to Wealthy.

Among the standard and near-standard rootstocks, M XIII is variable in its behavior and should be discarded. M X and XV have no outstanding value. This leaves M XII and XVI as the most promising rootstocks in this class. Whether mature trees on these stocks will be any smaller than seedling-rooted trees is unknown to the writer. From our observations we would prefer McIntosh on M XVI to McIntosh on seedling roots.

The final evaluation of the semi-dwarfing rootstocks (M I and II and possibly VII) for commercial orchards is yet to be made. The writer feels that they have promise for the grower who does not like big trees in his orchard. Their great weakness is poor anchorage. This should be understood and overcome as far as possible. They should be planted about 20–30 feet apart and given good growing conditions. Properly handled, they will bear younger and probably give larger acre yields of better apples than ordinary trees. They may not live as long, which may be an advantage.

Very dwarf trees on M VIII and IX have value only for the backyard where they are very satisfactory. They may be sprayed or dusted with hand outfits and given support if necessary. M IX propagates better, but the wood is more brittle than that of M VIII.

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Twelve Years' Results of Orchard Tests with Apple Trees on Selected Rootstocks, Kearneysville, W. Va.[1]

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THIS report presents additional results of apple rootstock research conducted at Kearneysville, West Virginia, by the West Virginia Agricultural Experiment Station and the Bureau of Plant Industry, United States Department of Agriculture. The particular planting covered by this report is designated as Block A.

While the first paper (4) should be consulted for more complete details, a very brief review of the more essential facts is given here.

In this orchard, the scion varieties, Gallia Beauty, Starking, Staymared, and York Imperial, are budded both on seedling and on clonal rootstocks.

The seedling rootstocks are from open-pollinated seed from the varieties Delicious, Grimes Golden, Jonathan, McIntosh, Northern Spy, Rome Beauty, Wealthy, and Winesap. French Crab also is represented in this orchard.

The clonal rootstocks are the clone Northern Spy; Malling I, XIII, and XV; and five clones from the United States Department of Agriculture, designated by the numbers 313, 316, 317, 323, and 329.

The trees were planted 20 by 20 feet apart in units of six trees on each rootstock and with a few exceptions these units were distributed in four places in the orchard. Rootstocks 316 and 329 are in alternate third rows to serve as standards with which to compare the others. In the majority of the scion-rootstock combinations, the original 24 trees had been reduced by losses, but in some combinations the number remained until the fillers of the Starking, Staymared, and York Imperial varieties were removed in the winter of 1941–42. The fillers of the Gallia Beauty variety were cut after the 1942 season. As Block A stood in 1945, the greatest possible number of trees of any of the combinations other than 316 and 329 was 12, a figure attained only in occasional instances.

YIELDS THROUGH THE 1944 SEASON

Table 1 presents the average total yield per tree for all varietal and rootstock combinations from the initiation of bearing through the 1944 season in comparison with the yields of the adjacent trees on 329.

Starking:—The yields of the Starking trees are the lightest of the four varieties; probably too much significance should not be attached to them. Starking/316 and Starking/317 are the only combinations including clonal rootstocks to yield significantly more[3] than the trees

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[1] Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 343.

[2] Mr. G. E. Yerkes, the propagator of the trees in Block A and also the original cooperator for the Bureau of Plant Industry in this project, has contributed some suggestions which have been incorporated in this report. All responsibility for their use lies with the author.

[3] For the purposes of this report, a difference of twice the standard error of the difference is assumed to be significant.

TABLE I—AVERAGE TOTAL YIELDS IN POUNDS PER TREE OF 12-YEAR-OLD APPLE TREES ON KNOWN ROOTSTOCKS AT KEARNEYSVILLE, WEST VIRGINIA (TREES ON EACH ROOTSTOCK COMPARED WITH THOSE ON ADJACENT NO. 329 ROOTSTOCK AS STANDARD)

Rootstocks	N*	M	D	S.E.D.	Rootstocks	N*	M	D	S.E.D.
		Gallia Beauty					*Starking*		
317 (c)	11	1,070	+338	121.29	316 (c)	37	440	+214	34.41
323 (c)	9	1,019	+322	121.66	Jonathan (s)	9	368	+145	73.54
316 (c)	38	946	+257	59.87	317 (c)	11	365	+125	50.98
Malling XV (c)	12	868	+119	132.51	323 (c)	10	344	+116	76.06
Malling XIII (c)	5	781	+ 84	77.32	Malling I (c)	12	335	+107	67.41
Rome Beauty (s)	9	810	+ 78	94 27	Malling XV (c)	9	327	+104	63.93
313 (c)	11	636	+ 58	87.87	313 (c)	7	272	+ 68	40.32
McIntosh (s)	9	786	+ 54	146.03	Delicious (s)	8	292	+ 64	70.56
Northern Spy (s)	10	596	+ 18	92.31	McIntosh (s)	10	303	+ 63	53.65
Winesap (s)	9	567	− 1	114.65	Northern Spy (c)	12	263	+ 59	43.46
Jonathan (s)	9	742	− 7	155.31	Wealthy (s)	9	281	+ 58	66.30
Northern Spy (c)	12	553	− 25	69.46	Northern Spy (s)	11	208	+ 4	51.34
French Crab (s)	12	654	− 95	130 24	Winesap (s)	6	201	− 3	34.67
Delicious (s)	11	602	− 95	91.79	Rome Beauty (s)	11	195	− 45	41.88
Grimes Golden (s)	11	632	−100	93.02	French Crab (s)	7	173	− 50	63.89
Wealthy (s)	10	635	−114	142.23	Malling XIII (c)	5	164	− 64	57.43
Malling I (c)	8	578	−119	76.09	Grimes Golden (s)	10	116	−124	42.95
		Staymared					*York Imperial*		
Northern Spy (c)	11	789	+214	79.70	323 (c)	11	568	+218	94.15
Northern Spy (s)	11	754	+179	101.85	McIntosh (s)	6	554	+194	119.83
316 (c)	38	874	+100	65.05	316 (c)	40	530	+181	41.06
French Crab (s)	12	956	+ 70	110 04	317 (c)	12	502	+142	56.63
Jonathan (s)	11	940	+ 54	110.01	Northern Spy (s)	8	351	+ 92	86.39
323 (c)	11	688	+ 11	142.11	Jonathan (s)	10	507	+ 65	102.97
Malling I (c)	10	677	0	123 11	313 (c)	9	283	+ 24	40.46
Wealthy (s)	11	814	− 72	106.72	Wealthy (s)	8	416	− 26	70.73
313 (c)	11	430	−145	83.97	Malling XV (c)	11	402	− 40	75.18
Winesap (s)	10	430	−145	82.97	Malling XIII (c)	7	298	− 52	80.57
Malling XV (c)	10	720	−166	106.15	Rome Beauty (s)	9	288	− 72	40.16
317 (c)	10	813	−178	111.18	Winesap (s)	3	159	−100	53.31
Delicious (s)	8	482	−195	128.74	French Crab (s)	11	309	−133	68.79
Grimes Golden (s)	8	748	−243	112 11	Grimes Golden (s)	10	214	−146	37.73
Malling XIII (c)	10	370	−307	98.59	Delicious (s)	6	203	−147	50.77
McIntosh (s)	3	633	−358	182.32	Northern Spy (c)	9	104	−135	37.12
Rome Beauty (s)	8	549	−442	116.67	Malling I (c)	10	126	−224	43.66

*N = Number of trees; M = average total yield in pounds per tree (from start of bearing through the 1944 season). D = Differences from the yield of the given variety on 329 rootstock. S. E. D. = Standard error of differences. (c) = Clone. (s) = Seedling.

on 329. Starking/Jonathan is the only combination in Block A including a seedling rootstock with a yield significantly superior to 329. Starking/Grimes Golden is the sole member of the Starking group to yield significantly less than Starking/329. Starking is less sensitive to rootstock influences than are the other three varieties in Block A.

Gallia Beauty:—The Gallia Beauty trees have continued to hold their lead over the other 3 varieties in average total production but the margin appears to be decreasing as the generally larger Staymared trees come into heavier production. Gallia Beauty on 316, 317 and 323 still maintains first rank among those of this variety. The relative positions of Gallia Beauty/Jonathan, and Gallia Beauty/McIntosh have dropped since the 1941 season (3). In consequence, on none of the seedling rootstocks has Gallia Beauty continued to yield in the same class as with 316, 317, and 323. On the other hand, no rootstocks, seedling or clonal, worked to Gallia Beauty has induced yields through 1944 significantly inferior to those of Gallia Beauty/329.

York Imperial:—The production of York Imperial ranked a poor third through 1944 although the average yield was superior to that of

Starking. York Imperial on 316, 317 and 323 continued to produce significantly more than on 329. No seedling rootstock worked to York Imperial has placed in this select group although McIntosh might have qualified had there been more trees of this combination. On the other hand, York Imperial on French Crab, Grimes Golden and Delicious seedlings have all yielded significantly less than on 329, while York Imperial/Winesap has barely avoided that class. Among the clones, York Imperial/Northern Spy clone and York Imperial/Malling I have been light producers with the latter exhibiting a high degree of uncongeniality as shown by miniature sized trees and very light yields. To all intents and purposes, York Imperial/Malling I was dropped from serious consideration in 1937 when the dwarf trees attempted to bear an impossibly heavy crop in their fifth season in the orchard (3). York Imperial is very sensitive to rootstock influences, according to the evidence in Block A.

Staymared:—With Staymared, the only yield record significantly superior to 329 was obtained on Northern Spy clone, although Staymared/316 was second among the clones. Staymared is the only variety in Block A which has placed so poorly on 317. While none of the seedling rootstocks was in the group with superior production, the Northern Spy seedlings almost placed there. Staymared on Grimes Golden, Malling XIII, McIntosh, and Rome Beauty has yielded significantly less than on 329; Staymared/Winesap seedlings and on 313 probably could be included here. Staymared/Malling XIII was by far the lightest yielder among both clones and seedlings. The relatively low placing of Staymared on 317, McIntosh, Grimes Golden, and Rome Beauty was due partly to the fact that the Staymared/329 trees used for a standard of comparison were unusually heavy yielders.

TRUNK CIRCUMFERENCE AFTER THE 1944 SEASON

Table II presents the average trunk circumferences after the 1944 season for each varietal and rootstock combination in comparison with the circumferences of the adjacent trees on 329.

A comparison of Tables I and II will show that while there is a tendency for a heavier yielding combination to have a larger trunk circumference and, inversely, for a lighter producer to have a smaller girth, such generalizations do not always hold true for a specific instance.

For example, Gallia Beauty/Winesap, Starking/French Crab, Staymared/Grimes Golden, and York Imperial/French Crab all possessed comparatively high rank as regards trunk circumferences but very low comparable positions with respect to their yields. In marked contrast, all four varieties on 316 ranked higher in both criteria, to name but one rootstock.

Some combinations had comparatively small trunk circumferences but high yields. This group is typified by Gallia Beauty/Malling XV, Starking/317, York Imperial/323, and York Imperial/McIntosh. In contrast to this class, Gallia Beauty/Malling I, Gallia Beauty/Wealthy, Gallia Beauty/Grimes Golden, York Imperial/Northern Spy clone,

TABLE II—Average Trunk Circumferences in Millimeters of 12-Year-Old Apple Trees on Known Rootstocks at Kearneysville, West Virginia. (Trees on Each Rootstock Compared With Those on Adjacent No. 329 as Standard)

Rootstocks	N*	M	D	S.E.D	Rootstocks	N*	M	D	S.E.D.
Gallia Beauty					*Starking*				
323 (c)	9	529	+ 37	20.53	Jonathan (s)	9	640	+127	30.78
Winesap (s)	9	504	+ 31	30.81	Malling XV (c)	9	598	+ 85	27.88
316 (c)	38	499	+ 6	9.96	French Crab (s)	7	595	+ 82	37.16
317 (c)	11	507	+ 1	16.76	Wealthy (s)	9	547	+ 34	28.45
McIntosh (s)	9	506	0	15.28	316 (c)	37	620	+ 34	18.73
Jonathan (s)	9	501	- 1	22.44	323 (c)	10	588	+ 9	27.56
Delicious (s)	11	489	- 3	14.37	Malling XIII (c)	5	581	+ 2	30.21
Malling XIII (c)	5	487	- 5	14.41	Winesap (s)	6	601	- 3	36.05
Rome Beauty (s)	9	499	- 7	17.61	Malling I (c)	12	560	- 19	22.43
Northern Spy (s)	10	466	- 7	23.99	313 (c)	7	581	- 23	23.30
Malling XV (c)	12	485	- 17	17.06	Delicious (s)	8	549	- 30	32.03
313 (c)	11	445	- 28	18.58	Northern Spy (s)	10	573	- 31	17.51
French Crab (s)	12	466	- 36	26.39	Grimes Golden (s)	10	576	- 48	20.79
Northern Spy (c)	12	418	- 55	25.20	Northern Spy (c)	12	550	- 54	17.00
Grimes Golden (s)	11	468	- 38	19.37	Rome Beauty (s)	9	565	- 59	20 68
Wealthy (s)	10	431	- 71	24.76	317 (c)	10	561	- 63	34.03
Malling I (c)	8	418	- 74	19.96	McIntosh (s)	10	558	- 66	18.13
Staymared					*York Imperial*				
Winesap (s)	10	591	+ 1	30.31	Jonathan (s)	10	631	+ 16	21.01
Golden Grimes (s)	8	615	- 17	29.65	French Crab (s)	11	607	- 8	23.11
Malling I (c)	10	554	- 20	17.12	Winesap (s)	3	574	- 10	24.95
323 (c)	11	550	- 24	22.61	Malling XIII (c)	7	585	- 17	27.43
Northern Spy (s)	11	562	- 28	16.23	Malling XV (c)	11	592	- 23	23.27
316 (c)	38	573	- 40	13.19	316 (c)	40	582	- 25	10.41
Delicious (s)	8	528	- 46	25.01	Northern Spy (s)	7	554	- 30	29.65
Rome Beauty (s)	8	585	- 47	27.00	317 (c)	12	588	- 33	33.36
Northern Spy (c)	11	542	- 48	14.89	313 (c)	9	547	- 37	27.53
Jonathan (s)	11	598	- 55	26.97	McIntosh (s)	6	581	- 40	44.21
French Crab (s)	12	575	- 78	28.16	Wealthy (s)	8	572	- 43	24.34
Malling XIII (c)	10	496	- 78	27.49	323 (c)	11	557	- 45	15.90
McIntosh (s)	3	549	- 83	36.30	Delicious (s)	6	550	- 52	29 63
317 (c)	10	539	- 93	33.80	Rome Beauty (s)	9	519	-102	39.66
Malling XV (c)	9	558	- 95	24 00	Golden Grimes (s)	10	462	-159	38.13
313 (c)	11	490	-100	17.19	Northern Spy (c)	9	367	-217	24.98
Wealthy (s)	11	551	-102	24.93	Malling I (c)	10	374	-228	21.75

*N = Number of trees; M = Average trunk circumferences in Mn. D = Differences from the circumference of the given variety on 329 rootstock. S.E.D = Standard error of differences. (c) = Clone. (s) = Seedling.

and York Imperial/Malling I placed very low in both yields and trunk girths.

In other instances, the same rootstock worked to several varieties has exhibited marked contrasts. Gallia Beauty/323 was significantly superior to that variety on 329 in both yield and girth; York Imperial/323 has placed first in yield but comparatively lower than 329 in circumference. With Starking and Staymared, 323 has performed in both respects much the same as 329. Starking/317 was relatively high in yield but next to the smallest in comparative girth; with the other three varieties, 317 placed in positions relatively similar with regard to both measurements of tree performance.

While trunk circumferences have been shown not always to be in close agreement with the weights of the tops (3), they remain the most practical tree growth measurement for a planting of apple trees of the extent of this orchard. This is especially true under the existing conditions. Although yield is the primary standard of tree performance, the girth undoubtedly possesses some value, when its limitations are kept constantly in mind in drawing conclusions.

Discussions

The yields of all four varieties worked on the clones 316 and 317, especially the former; have generally been excellent. With Staymared/317 the yield has been in the lower range of the intermediate group with 329; as explained previously, the 329 standard was unusually good in this comparison. With both Starking and Staymared, 323 has dropped into the same intermediate class as 329. Staymared/Northern Spy clone has been an outstanding combination in yield, whereas York Imperial/Northern Spy clone has been a very poor producer.

Among the seedling rootstocks, only Jonathan when worked to Starking has placed in the group with yields significantly greater than on 329. Northern Spy seedlings have performed about as well as Jonathan with Staymared, York Imperial and Gallia Beauty. The combination Gallia Beauty/Northern Spy seedlings was just average in yield but so was Gallia Beauty/Jonathan. In no instance with the four scion varieties tested has either of these two seedlings, Jonathan or Northern Spy, failed to yield at least as well as 329.

Wealthy has been intermediate in yield with Starking, Staymared and York Imperial; while Gallia Beauty/Wealthy is not a significantly lower producer than 329, this combination ranks just above the last-place Gallia Beauty/Malling I.

Regardless of the relative trunk circumferences, the yields of all varieties on Grimes Golden seedlings have been outstandingly poor; this fact is one of the most striking results thus far from Block A. Only with Staymared have the French Crab seedlings produced especially well, while York Imperial/French Crab has done very poorly. Starking/French Crab has a record that is but little better. This particular lot of French Crab has demonstrated no striking qualities as rootstocks thus far.

Delicious seedlings have made an unsatisfactory showing except possibly with Starking; York Imperial/Delicious has yielded significantly less than on 329. Winesap seedlings have not been promising, especially with York Imperial. With Gallia Beauty alone have Rome Beauty seedlings induced average yields, while Staymared/Rome Beauty has the lowest yield for that variety.

McIntosh seedlings have done exceptionally well only with York Imperial, although merely on the borderline of being significantly superior in yield. Gallia Beauty/McIntosh and Starking/McIntosh have produced about the same as these varieties on 329. Staymared/McIntosh has a very poor production record.

Malling I worked to York Imperial and to Gallia Beauty has resulted in low production, while with Staymared and Starking the yields have been in the intermediate class with 329. The outstanding instance of uncongeniality observed thus far in Block A has been York Imperial/Malling I, although York Imperial/Northern Spy clone may now be considered to have entered the same class.

Malling XV has been the most consistent performer of the three rootstocks of the Malling series under test in Block A. Trees of Gallia Beauty and York Imperial on Malling I are peculiarly subject to wind injury (2). Malling XIII would appear at present to possess no particular merit under conditions at Kearneysville.

Perhaps the principal reason why the general performance of the variety seedlings fails to be more outstanding is the excellent record of the clones 316, 317 and 323. Even 313 and 329, the least impressive members of the group, have a production average considerably above most of the seedlings. As grown at Kearneysville, the trees of these combinations have been productive, generally large sized, and have shown on the average a somewhat greater tendency to wind injury than is desirable.

In spite of any superior qualities inherent in them it is believed that a very long time will pass before the commercial fruit growers of the Cumberland-Shenandoah Valley Region will demand an appreciable quantity of apple trees on clonal rootstocks.

Some of the rootstocks, seedling and clonal, like 313, which result in a smaller tree of the four scion varieties, may be found eventually to have a place if such individuals become desirable. The closer planting and the easier sprayability permitted by this type of tree may be of considerably greater importance in the future.

No evidence of any promising measure of resistance to black root rot, *Xylaria mali*, was exhibited by any of the seedling or clonal rootstocks growing in Block A, according to Fromme and Schneiderhan (1) who used in their test remnants of the nursery stock left over from planting Block A. This disease is a serious problem in the Shenandoah Valley, especially in new plantings on sites of former apple orchards and with individual resets in positions in existing orchards where the previous trees may have died with black root rot.

This report should not be interpreted as suggesting in any way that the use of French Crab seedlings should be resumed in American nurseries. The record of the Western seed represented in this orchard has been far more creditable on the whole than has this particular lot of French Crab.

SUMMARY

Throughout this report emphasis has been placed on the matter of yield, for within the limits of a given variety this is the primary concern of the fruit grower.

In Block A a heavy yield through 1944 has been produced more generally by a comparatively large tree; a lower yield has usually come from a smaller tree. Exceptions, including certain reverse situations, have been indicated. Starking has been the least affected by rootstock influences, while York Imperial remains the most sensitive in Block A.

The observations made at Kearneysville through the 1944 season indicate that both Jonathan and Northern Spy seedlings have served in general as superior seedling rootstocks for the varieties Gallia Beauty, Starking, Staymared, and York Imperial. The use of these Jonathan and Northern Spy seedlings, especially with Staymared or York Imperial, has produced results considerably superior to those which might have been expected from comparable lots of miscellaneous seed from Northwestern canneries, if the indications from Block A are assumed to hold true. Western seed would very likely be a mixture especially of Delicious and Winesap seed, neither of which have particularly creditable performance records through 1944 at Kearneysville. On the other hand, Western seed has performed in general at least as creditably as the one lot of French Crab tested. There is no reason indicated for the desirability of a return to the use of French Crab in American nurseries. Some of the rootstocks inducing tops of less than standard size may assume in the future more prominence in the production of smaller trees.

The clonal rootstocks U. S. D. A. 316, 317 and 323 have generally outyielded the seedling rootstocks in Block A. Regardless of their performance when worked to the four varieties in this orchard, there are no present indications of any potential demand for these clones on the part of the commercial apple growers in the Shenandoah Valley.

The fact should be emphasized that these trees are only in their twelfth year and that the picture may change considerably with some of the combinations as the annual records accumulate. This possibility is especially apparent with Starking which has yielded poorly thus far. Radical shifts in relative ranks are more to be expected with the combinations placing other than significantly inferior in performance to 329; this is because many of the combinations obviously poor at present would appear to be physically incapable of any marked improvement in their status.

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Growth and Fruitfulness of Two Apple Varieties, Winesap and Delicious, on French Crab Seedlings and on the T–200 Clonal Rootstock[1]

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An orchard planting to compare the growth and yield of apple trees on a clonal rootstock with those on French crab seedlings was set out in the spring of 1927 by the West Virginia Agricultural Experiment Station at Morgantown in cooperation with the United States Department of Agriculture. The purpose was to gain additional information on the question whether a clonal rootstock, developed from a seedling similar to those in general commercial use at that time as rootstocks, would tend to increase uniformity in orchard performance.

The original seedling from which the clone was developed was chosen from a shipment of 5,000 1-year, grade 1, branched seedlings grown in a commercial nursery at Toppenish, Washington. For details of its selection and vegetative propagation, a previous report (2) should be consulted.

The degree of slope in the orchard varies from about 5 to 30 per cent with very irregular contours. At the upper side and one end, the soil possesses effective depths to bedrock of 18 inches to 3 feet depending on the location; several trees in that area have gone out because of drouth. At the lower corner, about one-quarter of the block has between 2 and 3 feet of topsoil deposited over the original soil profile; this was washed in from cultivated areas adjoining the site before the orchard was set. The soil in that area is imperfectly drained.

The block was set 20 by 20 feet on the diagonal system. The trees on T-200 and on the seedlings were planted alternately in the row throughout the tract which subjects both rootstocks to as near equal influence of the soil variability as any arrangement that could be made.

The planting consisted originally of 98 trees of Winesap and 96 of Delicious with an equal number on each rootstock. Of these, 42 of the former variety and 51 of the latter were lost in December, 1937, when alternate rows were removed. The statistics regarding these trees, as well as of those remaining, were presented previously (1, 2). During the 11-year period, 1927–1937, inclusive, 20 trees died, of which 14 were on seedlings and 6 on T–200. In the 7 years from 1938 through 1944, four more trees on the seedlings died, while one more on the rootstock T–200 went out, so that a total of 18 on seedlings and 7 on T–200 were lost.

The orchard is in a weedy grass sod which has been unbroken since the trees were well established. Pruning has been confined chiefly to light thinning. The growth of the trees is not equal to what one would expect of even-age trees on the vastly superior limestone soils of the Shenandoah Valley. On the higher portions of the block where the soil is shallow, the trees are smaller than the average of the planting;

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this is also true for those on most of the low part of the area where the soil is deep but where internal drainage is not as adequate as is desirable.

YIELDS

Table I presents the average total yields in pounds per tree for the 18-year period from 1927 through 1944.

TABLE I—COMPARISON OF AVERAGE TOTAL YIELDS PER TREE, MORGANTOWN, WEST VIRGINIA, ORCHARD, FOR THE 18–YEAR PERIOD, 1927–1944, INCLUSIVE. NEITHER OF THE DIFFERENCES IS SIGNIFICANT

Rootstock	Average Total Yields Per Tree (Pounds)			
	Winesap		Delicious	
T-200	24*	1740 ± 91.1**	21*	1888 ± 94.1**
French Crab	19	1609 ±169.6	19	1927 ±130.3

*Number of trees of the particular combination.
**Standard errors

With Winesap, the yield on T–200 is higher than on French Crab but not significantly so. With the 1944 crop, the Delicious/French Crab yield excelled those of Delicious/T–200 for the first time, although the difference is not significant. While the Winesap variety has produced with greater regularity than the Delicious, the former is out of place at Morgantown. Delicious is at least as temperamental as normally expected; the 1943 season was a total crop failure with this variety.

TRUNK CIRCUMFERENCES

Table II shows the average trunk circumferences in millimeters. Both Winesap and Delicious have significantly smaller circumferences on T–200 than on French crab.

TABLE II—COMPARISON OF AVERAGE TRUNK CIRCUMFERENCES, MORGANTOWN, WEST VIRGINIA, ORCHARD, 1944. BOTH DIFFERENCES ARE HIGHLY SIGNIFICANT

Rootstock	Average Trunk Circumferences (Mm)	
	Winesap	Delicious
T-200	714 ±20	685 ±14
French Crab	818 ±22	791 ±20

In the report after the 1937 season (2), it was noted that early in the development of the orchard, the Winesap/T–200 combination was dwarfing as shown by top weights, trunk circumferences, and visual observations.

Both the 1944 circumferences and visual observations indicate that this is still the case. With Delicious in 1937, there were no significant differences in top weights or in trunk circumferences; in 1944, the Delicious/T–200 combination is significantly smaller in trunk circumferences and a difference in the same direction is present in the tops.

COEFFICIENTS OF VARIABILITY

There are no important changes in the coefficients of variability since the report after the 1943 season (1).

The tendency is still present for the trees on the clonal rootstock, T-200, to possess somewhat greater uniformity in growth and yield. However, this is not apparent to the eye and would not be detectable without the data. The degree of superior uniformity observed would not be of any economic importance to the commercial fruit grower.

SUMMARY

This report presents data after 18 years in the orchard on yields, trunks circumferences, and coefficients of variability for a planting of Winesap and Delicious apple varieties on the clonal rootstock USDA T-200 and on French crab seedlings.

Neither of the differences in yield possesses significance. The trunk circumferences are significantly smaller for both varieties on T-200.

The clonal rootstock USDA T-200 is chiefly of experimental interest; it has not been propagated by the Bureau of Plant Industry for many years. The length of the period this rootstock has been under observation is probably its greatest contribution.

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Summary Report of Twenty Years of Rootstock Work with Tree Fruits at Maryland Agricultural Experiment Station[1]

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EARLY work on this project (1, 2) dealt with attempts to propagate apple trees from stem cuttings. Many thousand cuttings were placed under various treatments designed to induce rooting. A very few cuttings produced roots. In 1932, a method was reported (10) by which apple shoots, were etiolated with tape before the cutting was taken. Quite a number of such cuttings developed roots in the usual media, indicating this method as promising for experimental work on such material.

In work on self-rooting (own-root development) of apple trees, several commercial varieties were propagated by the nurse-root method and thus induced to produce root systems of self-roots (9). Two hundred trees of Stayman and Arkansas with self-roots are now 20 years of age, apparently maintaining vigor of growth and productiveness. More, recently, in 1935, work on self-rooted trees of 45 comestible varieties showed (17) that many varieties produced root systems definitely characteristic in many respects for each variety. Thus it becomes important to know the root characteristics of varieties and wild apple species under several soil conditions in making clonal stock selections.

In attempting to propagate apples by root cuttings (5, 6, 7), it was found that the use of variety roots from self-rooted trees failed in all but a small percentage of the material, although 50 varieties and 4000 cuttings were used. Roots of French crab seedlings were very successfully propagated as root cuttings. It is suggested that roots be taken from the original tree of a variety, especially of new varieties that are introduced, if root cuttings are to be used. A nurse-scion of French crab on a variety root assisted the variety root-cutting to form new roots, indicating that the French crab furnished something to the variety. It was found also that roots of 1-year-old seedlings of apple, peach, pear and several other species propagated much more readily as root cuttings than did roots of 2-year seedlings or older material.

Work with propagating media (10, 11, 12) of sand and peat involved the use of 43 species of fruits and ornamentals. Sand as a medium for cuttings resulted in the production of coarse brittle roots. A mixture of sand and peat resulted in fine textured roots with 30 species. Of several factors studied, aeration and moisture were considered as affecting the type of root development. The exodermis was less developed in peat which may explain the production of more lateral roots.

In the propagation of stocks from seeds (16, 23), a study of the effect of drying before and following after-ripening of the seeds showed that drying before after-ripening had no effect on germination but *drying of the seed following after-ripening* had serious effect in preventing germination. This work indicated the need of great care in regulation of moisture in the seed bed for apple, cherry, and peach seeds. Catalase activity in the seeds increased during after-ripening but little change in chemical content took place.

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In studies (3) of the factors affecting the vigor of the top growth on various stocks, it was found that the male parent of an apple seedling affects the vigor of a seedling and hence certain male parents should be avoided in gathering of domestic seeds. The caliper size of the apple stock has some influence on the nursery tree size, but some factor correlated with time of starting of the bud is the major influence (13). Two clonal stocks, Spy 227 and Vermont 323, have given greater growth of tops of some varieties under orchard conditions; however, Spy 227 has not been compatible with Grimes. In detailed root-excavations of 5-year-old and 7-year-old trees of Delicious and Starking with these two stocks, the invigoration of growth of top was not explained on the basis of root development, although Vermont 323 did have more small roots and better distribution proportionately than the roots of French crab stock under the same varieties (18).

In a planting of 900 trees planted to compare five different domestic seedlings with French crab, as used under four commercial apple varieties, there have been no measurable differences in growth and fruiting of trees on the several stocks after 9 years (28). Thus, domestic seedlings of open-pollinated Fameuse, Tolman, McIntosh, Northern Spy and Rome proved satisfactory as stocks for apples.

In the collection of wild species as promising sources of apple stock material, the identification of such species becomes important especially when variations occur. A taxonomic study (17) led to a study of the chromosome counts of eight indigenous species obtained from the wild and from arboretum conditions. It was hoped to find biotic types which will produce uniform seedlings.

Recent studies (20, 21) on apple stocks also have led to methods of appraising apple clonal stock material in the nursery to determine quickly and more accurately the promising clons for further study. In a recent report involving 185 apple clons, including selected wildings, selected American and European clonal stocks, and several variety selections, six steps in the appraisal are outlined covering a 5 year period:

1. Bud the clon on domestic seedlings for compatibility test.
2. Make root grafts to show cion-rooting ability, and use such scion roots for propagation of the clon.
3. Observe budded trees two seasons for weaknesses and other tendencies.
4. Place some buds of comestible clons on the trees for test of compatibility.
5. Obtain weight of budded clons and observe type of roots developed.
6. Reset the stocks bearing comestible clons and one stock clon budling. Use others for trench layering.

The program of appraisal yields the potentialities of the stock, relative vigor compatibility, dry matter production, cion-rooting ability, propagation from root cutting, character of roots and ability to affect seedling roots.

In the interest of regional cooperation, it is pertinent to quote from a paper (21) on methods of stock-testing, as follows:

"To improve technique of stock-testing and make results more comprehensive, it is suggested that a Standard of Performance be obtained and used for rating fruiting varieties in different locations; that a standard integrant be chosen and used to integrate the unregulated conditions of the several stock tests to make it possible to interrelate the results; that self-rooted trees be the base of comparison of stock combinations and that unworked stocks be included in all tests to learn their natural growth habits and verify identifications".

The uprooting of trees by a hurricane which swept New England on September 21, 1938, and the removal of apple trees by orchardists in this region afforded an opportunity to observe the rooting habit of mature trees and some stock-scion relationships (24, 25). Certain varieties, such as McIntosh which were more easily uprooted, exhibited shallow root systems of a rope-like character, affording relatively poor anchorage. Sufficient evidence was accumulated to warrant a conclusion favoring the hypothesis that the apple scion does influence the character of the stock. Another important observation after the storm not previously shown in literature of apple propagation was clearly made that the graft union often was not complete with *no exterior* indication of the poor union which was found as trees broke off at this point.

The comparatively shallow rooting of many tree species was a noteworthy observation during a month of work in Connecticut, Massachusetts and Vermont. Later work with tractor-pulled trees in Maryland has substantiated observations made in New England (24).

Investigations (26) of "self-rooting" of Hibernal and Northwestern Greening apples led to a study of chromosome numbers which disclosed that Hibernal is a tetraploid (68 c.) and Northwestern is a diploid (34 c.). Some seedlings of N. E. Hansen's hybrids (Northwestern Greening x *Malus ioensis*) showed diploids and one triploid in the group with no explanation for the occurrence of the triploid, inasmuch as Northwestern Greening and *M. ioensis* both proved to be diploid.

The use of a layering method (22) on root grafts of 187 clons has shown that there are three types of self-rooting; first, no rooting, second, cion-roots only, and third, cion and shoot roots. The development of roots on shoots by this method is very important, since 90 per cent of the self-rooting occurred on the scion shoots, and the minor portion on the cion (see discussion of practical layering (32) in which this information is put to use). A root-graft layering method eliminates the continual maintenance of a layer-bed.

A comprehensive study (27) of "self-rooting" of *Malus domestica,* Gleishberg's and Hatton's stock types, and comestible varieties, involving 287 kinds of apple material rooted in a trench-layer, resulted in a classification selfroot-forming ability as follows:

"*Type 1.* Burr knot. A number of small roots initiate directly above the bud and then initiation continues around the sides and under the bud until a solid mat of roots is formed engulfing the bud."

"*Type 2.* Several small roots are formed at each, of one or more, points of root initiation, but do not spread to form a solid mat around the bud."

"*Type 3.* A type showing two roots usually initiating from one point; both roots coarse and usually covered with rootlets."

"*Type 4.* Roots usually appearing singly from points of initiation. These roots are usually coarse and are well covered with rootlets."

"*Type 5.* This type was typified by those which initiated roots primarily at the junction between mother and daughter plants."

"*Type 6.* Very few or no roots."

In a search for clonal stock sources this information on root-forming ability assumes great importance.

The influence of the source of scion wood on the amount of scion-rooting or self-rooting of apple varieties was shown (31) by a comparison of very vigorous scion-wood, obtained from decapitated young trees, with scion-wood obtained from bearing trees of low vigor. The scion-rooting of wood from bearing trees, as shown in the nursery grafts after 2 years, was much greater in terms of per cent of trees showing such scion roots, as well as amount of rooting of the varieties Stayman Winesap, York Imperial, Starking, and Gallia Beauty.

Rather clear indication of effect of scion variety on root configuration was found in the study (24) of bearing trees uprooted in New England by the storm of 1938. The uprooting of trees appeared to be definitely related to the variety; as, for example, McIntosh was particularly hard hit by the storm. Later in an extensive nursery study (31, 32) of effect of scion-variety on root configuration of various stocks, it was concluded that perhaps only 20 per cent of our apple varieties would consistently induce specific characteristic root disposition of the stock.

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Lethal Effects of Certain Apple Scions on Spy 227 Stock

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The clonal apple stock Spy *227* has been of special interest ever since it was found that, although it was a very satisfactory stock for certain varieties of apples, other varieties grafted or budded onto it died in a relatively short time. Yerkes and Aldrich (1) have summarized the history of this stock and recorded a number of observations relative to its behavior when worked to a large number of scion varieties. The purpose of this report is to record additional observations and data relative to the interesting relationships of this stock to certain scion varieties and scion sources.

Behavior in Cases of Failure:—Buds of lethal varieties inserted in stocks of Spy *227* grow well in their first season during the summer and into the early fall but then begin to show evidence of decline indicated by leaf color, early defoliation, and frequently terminal blossom bud formation. Root examinations disclose that by this time nearly all of the rootlets are dying back from the tips toward the axis. Root deterioration continues to progress so that by spring practically the entire root system is dead or dying. The tops, however, appear to be healthy and leaf out in the spring only to wither and die for lack of a supporting root system. Although most of the varieties that fail on this stock follow this brief pattern of existence, some, as pointed out by Yerkes and Aldrich, survive for a somewhat longer period. The peculiar behavior described above made it apparent that a special type of incompatibility is involved between this clone and certain scion varieties, and a number of preliminary experiments were undertaken in an effort to determine the nature of this uncongeniality.

Stock and Scion Combinations in the Nursery:—Many combinations were tried in which two buds were inserted opposite each other on the same stock plant, one bud being of a congenial variety, the other of a lethal variety. When the stock top was cut back both buds were allowed to grow. Such combinations invariably followed the usual pattern of failure, showing that the congenial variety did not protect the plant against the harmful action of the lethal variety and that the death of the Spy *227* roots was not due to a lack of some essential metabolite from the top but instead could probably be attributed to some positive toxic principal contributed by the lethal variety or some modifying effect on the absorptive powers of the Spy *227* root.

Other combinations were devised in which a scion of a lethal variety was bench-grafted to two root pieces, one root being Spy *227* and the other a French crab or other seedling root piece, in such manner that both root pieces joined the scion. Such combinations produced successful trees but upon digging it was found that in all cases the Spy *227* root had died and that the tree was supported by the nonsusceptible seedling root. The experiment indicated that the lethal action involved in the case of this clone was not due to some influence of certain scion varieties on the ability of the Spy 227 root system to absorb certain essential mineral elements, for in the above case the other root could have acted for the entire grafted combination.

Further graft combinations with a lethal scion were tried in which the two different root pieces were united end to end with Spy 227 as the bottom piece. This combination also resulted in successful trees but with death of the Spy 227 root portion. When Spy 227 root was used as the intermediate root piece and seedling root on the bottom the combination barely started growth or died without starting.

Results with Established Orchard Trees:—A number of varieties that had proved successful on Spy 227 in the nursery were planted on this stock in the orchard at the Plant Industry Station, Beltsville, Maryland, in the spring of 1930. Among these varieties were Jonathan, Yellow Transparent, and Starking, all of which grew well and were above average size for these varieties at the end of four growing seasons. An astonishing effect on these orchard trees, demonstrating the lethal action of certain varieties for Spy 227 roots, was obtained entirely without intent in the course of an unrelated problem, the outcome of which now follows..

In the early spring of the fifth growing season five trees of each of these varieties were partially grafted each to six other varieties, namely, Yellow Transparent, Jonathan, Golden Delicious, Delicious, Winesap, and Yellow Newtown. Only one scion of each variety was set in each tree. The scions were set in lateral branches because the purpose of the experiment was to grow fruit on these lateral branches nourished chiefly by the foliage of the main tree variety. Thus the scions were set in secondary rather suppressed branches rather than leaders. The total wood removed in grafting these branches did not represent over 5 per cent of the top of the tree, and the new growth from the grafted scions represented an even smaller proportion of the entire top. Whip grafts were used and were set at the time growth was started.

At the end of two years it was noted that every one of the five trees of each of the three varieties on Spy 227 stock in which grafting had been done was dead or dying. Since such a result was completely unexpected, no detailed record had been made when the visible deterioration of these trees started. Companion trees in an adjoining row of the same variety on the Spy 227 rootstock continued to grow vigorously and are still healthy in the orchard. Also trees of Golden Delicious and Yellow Newtown that were on seedling rootstocks and that were similarly grafted have remained healthy.

Two of the scion varieties used in this topworking, i. e., Winesap and Yellow Newtown, have generally, though not always, proved lethal when worked directly on Spy 227 in the nursery. The experiment outlined above demonstrated conclusively, however, that one or more of the scions set in these trees were lethal under the conditions of this test. In all cases a minimum of 4 lineal feet of intermediate variety wood was interposed between the scions and the Spy 227 stock.

Following the observations outlined above an additional experiment was performed on the effect of inoculating 6-year-old apple trees growing on Spy 227 rootstock with a toxic scion variety. In the fall of 1939, buds of Stayman Winesap were inserted in the current year's shoots of Chenango and Golden Delicious trees, all 6 years of age and uniformly vigorous and healthy in appearance. Of the trees of each variety in the test, one of each was not budded. The other four trees of each variety received 1, 2, 4, or 8 buds, respectively, of Stayman Winesap. The results of this test are reported in Table I. Some of the trees in which Stayman Winesap buds were set were showing evidence of deterioration by the fall of 1939 after one season's growth of the buds, and by August 1940 most of the trees were deteriorating. All of the trees were dead or dying 3 years after the buds were set. The trees set with 4 or 8 buds deteriorated somewhat earlier than those set with 1 or 2, but all trees succumbed within a 4-year period. The Golden Delicious trees proved more resistant to the toxic influence than did Chenango.

TABLE I—EFFECT OF THE NUMBER OF STAYMAN SCIONS ON THE RATE OF KILLING OF VIGOROUS 6-YEAR-OLD CHENANGO AND GOLDEN DELICIOUS TREES GROWING ON SPY 227 ROOTSTOCK, TOPWORKED IN THE FALL OF 1939

Number of Stayman Scions on Each Tree	Variety of Tree Topworked	Relative Rating of Trees*				
		Sep 1939	Aug 1940	Aug 1941	Aug 1942	Aug 1943
0 (check)	Chenango	3	3	3	3	3
	Golden Delicious	3	3	3	3	3
1	Chenango	3	2	1	0	0
	Golden Delicious	3	3	3	2	1
2	Chenango	3	2	1	0	0
	Golden Delicious	3	3	2	2	1
4	Chenango	2	1	1	0	0
	Golden Delicious	3	2	2	1	0
8	Chenango	2	1	0	0	0
	Golden Delicious	3	2	1	0	0

*0 = dead
1 = a few green leaves present (tree almost dead)
2 = tip leaves yellow
3 = leaves green and tree apparently healthy

Lethal Effects from Dormant Buds:—In August 1940, buds of Rome Beauty were inserted into Spy 227 stocks growing in the nursery row. In the spring of 1941, 30 pairs of plants were selected. One plant of each pair was left intact, allowing the Spy 227 top to grow, which kept dormant the Rome Beauty bud that had been inserted. In the other 30 plants the Spy 227 top was cut back just above the Rome Beauty bud, which forced it into growth, producing a Rome Beauty top on the Spy 227 stock.

The plants with the stock tops cut back in the spring so that the Rome Beauty buds grew, followed the usual pattern already described for nursery trees. The buds grew well during the first season but in the spring of the second year the trees began to die. Some were dead by May 15, 1942, while a few lingered on until July 1. However, where the Spy 227 tops were not cut back and consequently the Rome Beauty buds remained dormant the plants died during the first summer, some dying as early as June 1, 1941, and all were dead by September 1.

The above experiment was repeated using Rome Beauty buds inserted in September 1941, but in this case half of the number of buds were without wood present in the bud shield and half, as before, with wood present. The presence or absence of wood in the bud shield did not alter the course of the outcome. By June 15 following budding, many of the trees with the Spy *227* tops still intact were showing a yellowing and dropping of foliage. A tree by tree examination of the root condition was made. Root growth of these trees was markedly affected as judged from the number of dying rootlets and absence of new root tips. On this same date the roots of the trees with stock tops removed were in much better condition showing quite a number of new roots still being formed. The experiment again emphasizes that failure of the trees begins with damage to the root system of Spy *227* and also that the progress of this lethal action is influenced by the amount of the top of the plant and probably also differs depending on the non-toxic scion variety accompanying the lethal bud or scion.

DISCUSSION

The evidence from these experiments indicates that apple scions from certain sources carry a principle that is highly toxic to Spy *227* roots. The Spy *227* may be inoculated and ultimately killed as a result of setting into the plant a single bud or a small quantity of bark material carrying the lethal principle. This circumstance suggests that the toxic principle can multiply in the host plant and would appear rather definitely to place it in the virus category. It seems highly probable that the toxic principle may be carried in a large number of varieties or may be carried in certain trees of a variety and not in other trees of the same variety. This would be in accordance with expectations if a virus were involved.

The results reported by Yerkes and Aldrich indicate clearly that the lethal effects of various scions on Spy *227* stock is not a simple variety relationship. In testing color strains of varieties, certain of these strains of Winesap have proved completely compatible with Spy *227* while others have died. Similarly, Jonathan remained healthy while Blackjon scions resulted in killing. Tukey and Brase (2) and Shaw and Southwick (3) have also reported that certain strains of varieties thrive well on Spy *227*, while other strains die. Although these results may be interpreted as due to genetic differences of the strains, they may also be explained on the basis of differences in source of the scions, some of which may have become infected with the virus. In the case of the Winesap sports which survive on Spy *227* the assumption is not illogical that the particular Winesap trees from which the sports were derived were at the time, at least, free of the virus and hence could not pass it on to sported selections. The possibility should not be overlooked, however, that the proposed virus cannot propagate itself in certain varieties and these therefore cannot act as carriers.

The lethal effect of inserting Rome Beauty buds into Spy *227* stock whether or not the Rome Beauty buds were forced into growth, is of particular interest. The fact that the trees succumbed more quickly when these buds were not forced into growth than when they were, would indicate either that the toxic principle (virus) builds up more rapidly in the Spy 227 top than in the Rome Beauty top, or that the relatively larger amount of top in the case where the Spy 227 top was not cut back permitted a faster build-up of the toxic principle. The fact that some apple varieties, when budded on this clone and the stock top is cut back in the usual way, result in more rapid death than is the case with other varieties suggests that the ability of the alleged virus to propagate itself within the host is influenced by varietal differences.

If it is true that a virus is responsible for the puzzling stock and scion relationships outlined here the virus simply exists as a masked entity and does no apparent harm to the varieties infected or to any known rootstocks except Spy 227 and certain, but not all, clones which have been developed from its seedlings. The possibility should be pointed out that the problem may be more complex than simply involving the presence of a virus in the varieties that are lethal to these stocks. Conceivably a second factor, perhaps a metabolite developed by certain varieties and not by others, is necessary for the lethal activity of the virus.

The intriguing problem of Spy 227, which in itself thus far appears to be of no practical or economic interest, bears a striking parallelism to the stock and scion relationships in the very important and highly destructive tristeza disease of citrus.

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An Orchard Test of Mazzard and Mahaleb Cherry Rootstocks[1]

By William S. Clarke, Jr. and R. D. Anthony, *Pennsylvania State College, State College, Pa.*

In the Proceedings of this society for 1937, a report was presented of the performance of mazzard and mahaleb rootstocks in three cherry orchards (1). Shortly after this date, the orchard at Arlington Farm, Rosslyn, Virginia, conducted by the U. S. Department of Agriculture, was removed because of a building program. The orchard at the Kearneysville field laboratory of the West Virginia Experiment Station was taken out in 1945 because of serious injuries from frosts and freezes. This is the final report of the third orchard at State College, Pennsylvania.

The cultivated cherries, both sweet and sour, are not native to North America, but sweet cherry seeds were so commonly carried by the early settlers that the cherry became the usual door-yard tree in much of Pennsylvania. From these early seedling trees the birds spread pits far and wide until the sweet cherry has become a common fence-row tree in those parts of the state where the elevation is not much above 2000 feet. These wild seedlings of the sweet cherry, *Prunus avium*, are commonly called "mazzards", both in this country and in Europe.

If the sour cherry was used at all in these early days, there has been practically no survival of seedlings or sprouts of *Prunus cerasus* around these century-old home sites, many of which are now marked only by clusters of apple, cherry, and pear seedlings or occasionally by the broken remnants of the original trees.

When commercial nurseries were started in this country in the first half of the last century, the sweet cherry was a popular fruit. The only stocks used were mazzards propagated from seeds secured in this vicinity or by digging seedlings from the fence rows and abandoned meadows. No other stock was commonly used until about 1860.[2]

In Pennsylvania at the present time, most commercial varieties of sweet cherries planted at elevations above 1000 feet frequently are injured by low temperatures; yet generations of natural selection have isolated strains of wild mazzards which now withstand temperatures of −20 to −30 degrees F without serious injury.

The business of growing rootstocks for export to America began to develop around 1860 (6) at the time that *Prunus mahaleb* was introduced to American nurserymen as a stock for cherries. The greater freedom of the mahaleb stock from attack by the leaf spot disease (*Coccomyces hiemalis* Higgins) as compared to the mazzard seedlings in the nursery soon developed a strong preference for mahaleb seedlings. Mazzard seedlings lined out in the nursery were frequently defoliated to such an extent that either budding was impossible, or too large a proportion of the buds failed to take.

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[2] The Farmers' Nursery was conducted by Asa and Daniel M. Anthony (grandfather and father of one of the authors) from about 1850 to 1864 or 1865 at Rochester, N. Y. They dug mazzards from the fence rows to use as stocks for sweet cherries. A large part of the output of this nursery was sold in south-central Pennsylvania for home planting. Other nurseries around Rochester at this period followed the same custom. Many sweet cherries of close to 100 years of age are still standing in Pennsylvania farm yards in areas where the life of present day commercial cherry trees is short.

One of the first studies of the relative merits of these two stocks in the mature orchard was that reported by Howe (7) in an orchard at Geneva, N. Y., planted in 1912 and consisting of sweet, sour, and Duke cherries on mazzard and mahaleb roots. After 14 years, Howe found that, with all three types of cherries, the mazzard roots gave higher survival, larger and more productive trees. The stocks for this test had been imported from France as seedlings, a practice which, by this time, had become common.

Shortly after the publication of Howe's bulletin, McClintock (8) suggested the use of seeds from American mazzards as a desirable source of stock material. He found nursery stock grown from French mazzard seeds much weaker and more susceptible to leaf spot.

When the Federal plant quarantine of 1931 practically shut off the further importation of seedlings, a few eastern nurseries began producing root stocks from seeds of near-by, wild mazzard trees. At least two Pennsylvania nurseries were pioneers in locating parent mazzard trees whose seedlings gave satisfactory results in the nursery. Several nurseries in the Pacific north-west also located satisfactory sources for both mazzard and mahaleb seeds.

In 1939, Bryant reported the results of an orchard test of these two rootstocks in Colorado (2) under arid conditions. In this orchard mahaleb seedlings proved a better stock for Montmorency sour cherry than mazzard.

In England, early in the century, the East Malling Research Station began a study of selected mazzards as a source of stock material. In the 1933 report of this work Grubb (4) noted considerable difference in the performance of different clones secured by vegetative propagation from these selected trees. This work has now advanced to such a stage that one selection, F 12/1, is supplying the clonal roots for most of the cherry plantings at East Malling (5).

One of the most recent reports of cherry rootstocks studies is that of Coe (3) covering tests in Utah of mazzard, mahaleb, and Stockton morello rootstocks for sweet cherries. These stocks were secured from commercial sources and, since the trees were planted in the spring of 1931, the seedlings were purchased before the Federal quarantine was established and so were probably of foreign origin, though Coe does not discuss this point. In this experiment the trees on mahaleb roots had trunk circumferences about 40 per cent larger than those on the other roots and were more hardy and outyielded the others.

Beginning about 1924, the Department of Horticulture at Pennsylvania State College undertook a study of selected wild mazzard trees in the vicinity of State College. Hundreds of these trees were growing in old fence rows, along the roadsides, and in abandoned fields. Some of these trees were at elevations of 2000 feet where temperatures of —20 degrees F were not uncommon.

For a number of years seedlings were grown from parent trees selected for apparent vigor and hardiness. Because the sweet cherry will not set fruit with its own pollen, a considerable degree of variability could be expected among the seedlings from the same tree; nevertheless, the seedlings from a single tree were surprisingly uniform; but much variation was noted between the different selections in such factors as the percentage of germination, uniformity and vigor of growth, and resistance to leaf spot infection. The results were not always the same from seeds gathered in two different years from the same trees.

Several individual trees were selected whose seedlings seemed most promising; seeds of these were supplied to a commercial nursery in southern Pennsylvania for the production of understocks. These were budded to sweet cherries in comparison with an adjoining block of mazzard stock of European origin. The native seedlings gave a higher "take" of buds and produced taller 1-year trees. In several other tests seedlings of these selected parents gave satisfactory results.

In a test started by the U. S. Department of Agriculture in 1908 at Arlington Farm near Washington, a considerable range of cherry varieties had been planted, each variety on mazzard and mahaleb roots of commercial origin. In the majority of cases the trees on mazzard roots lived considerably longer than those on mahaleb roots. In 1926, G. E. Yerkes, who was then in charge of rootstock studies for the Division of Horticultural Crops and Diseases, U. S. D. A., decided to establish a more extensive test of these two stocks in cooperation with the Pennsylvania and the West Virginia Agricultural Experiment Stations.

The selection studies then being made at State College suggested the desirability of studying the source of seeds as well as the species. Two selections were made in the summer of 1926. They were:

Lot 492[3]—Mazzard seeds from a very old tree at Bell, Maryland.

Lot 493[3]—Mahaleb seeds from a group of seedlings at Bell, Maryland, selected for uniformity of type and vigor.

When these seedlings were ready for lining out, the following seedlings were secured and planted with them at the Arlington Farm:

Lot 736—Mahaleb seedlings imported by W. & T. Smith Co., Geneva, N. Y.

Lot 737—Mazzard seedlings imported by W. & T. Smith Co., Geneva, N. Y.

Lot 738—Mahaleb seedlings grown by Thomas Rogers & Son, Winfield, Kansas, from imported seeds.

Lot 740—Mazzard seedlings grown by Washington Nursery Co., Toppenish, Washington, from trees selected in Washington. (It is not known whether these came from a single tree or a group of trees.)

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[3] These numbers are the Arlington Farm nursery numbers.

Lot 742—Mazzard seedlings grown by Louis Vistica, Stockton, California, from seeds of trees selected for desirability of type. (It is not known that these are from a single tree though this is believed to be the case.)

Lot 748—Mazzard seedlings from J. F. Jones Nursery, Lancaster, Pennsylvania from a tree selected by Mr. Jones in Virginia.

Lot 749—Mahaleb seedlings grown by J. F. Jones, Lancaster, Pennsylvania from imported seeds.

These seedlings were budded to seven varieties of sweet cherries, Montmorency sour cherry, and Saint Medard, a sour cherry imported by the U. S. Department of Agriculture from France. This cherry had been an outstanding variety in the early test at Arlington Farm. Although this cherry is called a sour cherry, there are some indications it may be a Duke.

From these trees orchard plantings were made at Arlington Farm, at Kearneysville, West Virginia, and at State College, Pennsylvania. This is the final report of the orchard planted at State College together with certain observations of the performance of selected mazzard trees.

The orchard at State College was planted in the early spring of 1929 on the north side of a low valley with a gentle westward slope. The lowest row of sweet cherries was along the floor of this valley. At the time this site was selected, air drainage was thought sufficient to prevent serious frost damage; instead there has been some damage nearly every year, and in some years the entire crop has been destroyed. The small valley in which the cherry orchard was planted is a side branch of a larger valley which is considerably restricted about a mile below the orchard. On still, cold nights the main valley fills with cold air, which drifts into the cherry orchard but seldom reaches an apple orchard about 300 feet south and about 20 feet higher. When conditions were excellent for heat radiation and the settling of cold air, there was frequently as much as 7 to 8 degrees F difference between these two orchards. On a night in January, 1942, the minimum temperature in the cherry orchard was −25 degrees F; on slightly higher ground a quarter of a mile away it was −13 degrees. On two nights in February, 1934, temperatures of approximately −30 degrees F were noted at the farm house 300 feet south of the cherry orchard and on higher ground.

The trees were planted in 20 foot squares but, in order to follow approximately the contour, the varieties were planted along the diagonals. Each diagonal row was a single variety and, in most cases, mazzard and mahaleb stocks alternated along the row. There were 14 rows of 14 trees each. Row A was the lowest one along the valley floor and lay nearly east and west. Table I shows the general plan of the orchard. On account of outcropping ledges of limestone rock, a few positions were left vacant.

Because of crop losses from low winter temperatures and frosts, yield records are not available. Trunk circumference measurements were taken a number of times during the experiment. Notes were

TABLE I—PLAN OF ORCHARD. FOURTEEN TREES IN EACH ROW

Row	Variety	Row Numbers	Stock	Source of Roots Lot Number	Number of Trees	Location of Parent Trees
A	Windsor	Odd	Mazzard	748	6	Virginia
			Mazzard	737	1	Europe
		Even	Mahaleb	493	6	Maryland
			Mazzard	492	1	Maryland
B	Black Tartarian	Odd	Mahaleb	493	6	Maryland
			Mahaleb	749	1	Europe
		Even	Mazzard	748	5	Virginia
			Mazzard	742	2	California
C	Windsor	Odd	Mazzard	742	7	California
		Even	Mahaleb	736	6	Europe
			Mazzard	492	1	Maryland
D	Schmidt	Odd	Mahaleb	736	6	Europe
			Mahaleb	738	1	Europe
		Even	Mazzard	748	6	Virginia
			Mazzard	742	1	California
E	Windsor	Odd	Mazzard	737	7	Europe
		Even	Mazzard	492	4	Maryland
			Mazzard	742	2	California
			Mazzard	737	1	Europe
F	Schmidt	Odd	Mazzard	492	5	Maryland
			Mazzard	737	2	Europe
		Even	Mahaleb	738	4	Europe
			Mazzard	742	2	California
			Mazzard	737	1	Europe
G	Black Tartarian	Odd	Mazzard	737	5	Europe
			Mazzard	740	1	Washington
			Mazzard	742	1	California
		Even	Mahaleb	749	7	Europe
H	Montmorency	Odd	Mazzard	748	7	Virginia
		Even	Mahaleb	736	5	Europe
I	Montmorency	Odd	Mahaleb	493	7	Maryland
		Even	Mazzard	737	5	Europe
J	Montmorency	Odd	Mazzard	492	5	Maryland
		Even	Mahaleb	749	7	Europe
K	Montmorency	Odd	Mahaleb	738	7	Europe
		Even	Mazzard	742	6	California
L	Saint Medard	Odd	Mazzard	492	7	Maryland
		Even	Mahaleb	493	7	Maryland
M	Saint Medard	Odd	Mahaleb	736	7	Europe
		Even	Mazzard	737	7	Europe
N	Saint Medard	Odd	Mazzard	748	7	Virginia
		Even	Mazzard	742	7	California

made of winter injury when such injury occurred. When the experiment was concluded in the fall of 1944, the trees were pulled with a tractor, the trunk cut off at the crown of the roots, and the entire top weighed. The roots were not weighed, as too many were broken off in the ground.

During the experiment an unexpected variable was discovered. Root sprouts were observed under a number of trees. In one case where mahaleb stock had been used the sprouts were not mahaleb. When the sprouts from under a number of trees in the Montmorency block were dug and planted in a nursery row, several proved to have typical Montmorency foliage. Although none of these was fruited, it is safe to assume that the Montmorency tree had become partly own-rooted. In one case these sprouts were traced to a single root. It is doubtful if such scion rooting was extensive enough to be a considerable factor in the results of the experiment. Root sprouts of this type have been observed frequently in commercial Montmorency orchards in the state.

The sweet cherries suffered severely from low temperature injury. Most of the Black Tartarian were dead by 1932. All of the Windsor were killed in the winter of 1932–1933 and in the following winter. The trees of Schmidt suffered considerably from winter injury, particularly to the trunks, but a number survived until the end of the experiment, a few in good condition. Of the 11 sweet cherries killed or seriously checked by the spring of 1930, nine were on mahaleb roots. There was very little winter injury to the trees in the sour cherry block; all but three trees survived to the end of the test. Because of the heavy loss of sweet cherries only the results with the two sour cherries will be reported in detail.

Although trunk circumference measurements were made from time to time during the life of the orchard, only those measurements made when the trees were discarded in 1944 will be considered here, using the cross section area of the trunks. Because of the very high correlation of trunk cross section area and weight of tree tops, only the latter will be presented in detail.

Table II gives the weight of tops of adjacent trees in the same row,

TABLE II—INFLUENCE OF SPECIES OF ROOTSTOCK ON THE WEIGHTS OF THE TOPS, WITH ODDS THAT THE ROOTS OF ONE SPECIES HAVE PRODUCED LARGER TREES THAN THOSE OF THE OTHER SPECIES (POUNDS, 1944)

Stocks		Gain	Stocks		Gain
Maz 748	Mah 736	Maz - Mah	Maz 737	Mah 493	Mah. - Maz.
		Montmorency			
557	40	517	—	321	—
365	99	266	270	438	168
430	122	308		309	---
499	180	319	508	366	142
149	155	294	261	225	36
287	-		--	221	—
347			158	181	- 23
Maz. 748 better than Mah. 736 Odds 1408 to 1			No significant difference		
Maz 492	Mah 749	Maz Mah.	Maz. 742	Mah 738	Maz.- Mah
		Montmorency			
221	181	40	297	37	262
180	214	- 34	224	128	96
-	217	—	195	156	39
206	153	53	235	93	142
313	109	204	138	61	77
79	291	212	—	62	—
--	32	-	142	79	63
No significant difference			Maz. 742 better than Mah. 738 Odds 126 to 1		
Stocks		Gain	Stocks		Gain
Maz. 492	Mah. 493	Maz - Mah.	Maz. 737	Mah. 736	Maz. - Mah.
		Saint Medard			
304	481	-177	311	505	-194
248	389	- 141	305	345	- 40
66	261	-195	318	447	- 99
223	347	- 124	243	370	-127
335	275	60	338	253	85
—	416	--	190	289	- 99
92	311	-219	153	160	- 7
Mah. 493 better than Maz. 492 Odds 89 to 1			Mah. 736 better than Maz. 737 Odds 21 to 1		

one on mazzard and the other on mahaleb roots, and the odds for any significant difference.

Table III presents the odds for significant difference in trunk cross section area.

TABLE III—INFLUENCE OF SPECIES OF ROOTSTOCK ON CROSS SECTION AREA OF TREE TRUNKS. ODDS THAT ROOTS OF ONE SPECIES HAVE PRODUCED LARGER TREES THAN ROOTS OF THE OTHER SPECIES

Stock Preference	Odds
Montmorency	
Mazzard 748 better than Mahaleb 736	84 to 1
Mahaleb 493 better than Mazzard 737	No significance
Mahaleb 749 better than Mazzard 492	No significance
Mazzard 742 better than Mahaleb 738	57 to 1
Saint Medard	
Mahaleb 493 better than Mazzard 492	107 to 1
Mahaleb 736 better than Mazzard 737	3.81 to 1

From these tables it is clear that, in this orchard, the tree performance of the two sour cherries has been as much influenced by the source of the seedling stocks and the scion variety as by the species of the rootstock (see Figs. 1 and 2). Because there is no reason to believe this orchard is abnormal, it would seem that further studies of cherry seedling rootstocks should involve a study of sources of stock rather than a comparison of mazzard against mahaleb roots.

When the stocks were selected in 1926 for this study, the work at State College with promising parent mazzards had not progressed to the point where it was thought desirable to use any of this material to supply stocks for the new experiment. During the continued study of seedlings from trees in the vicinity of State College, it became apparent that there was considerable variation in these seedlings in susceptibility to leaf spot disease. In a study of this resistance several

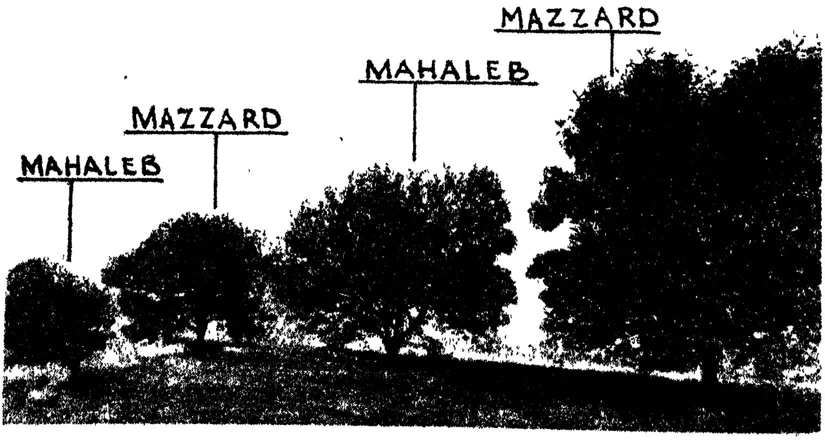

FIG. 1. Showing the variability of Montmorency on two stocks.

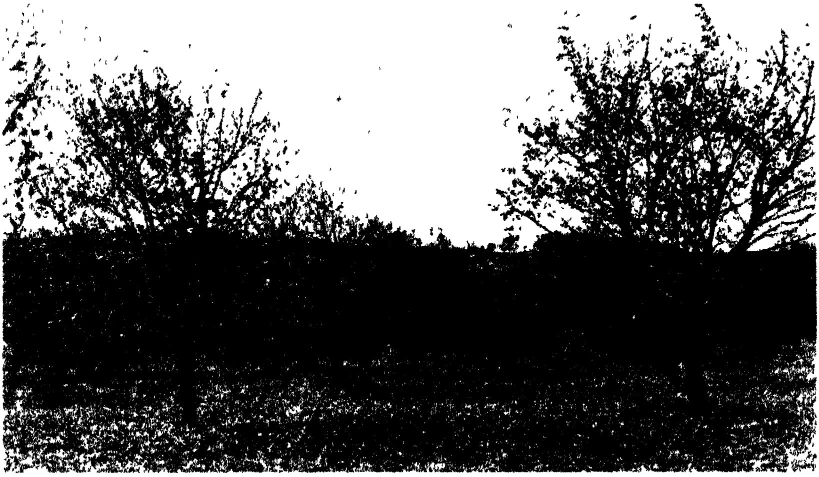

FIG. 2. Showing the uniformity of Saint Medard on two stocks.

hundred seedlings from several of the selected parents were planted at State College. Except for an occasional dormant spray these trees have been unsprayed. When any seedling showed much leaf spot it was discarded. In years when leaf spot was severe a considerable number of trees would be discarded. In 1945, 25 trees were still standing.

Leaf spot was more severe in 1945 than for many years. The Malling Clone, F12/1, has been grown alongside these seedlings, and its resistance to leaf spot attack has been used as a guide in discarding seedlings. In 1945, F12/1 had its first severe attack of leaf spot. None of the remaining 25 seedlings had enough leaf spot to justify marking it for discard. The next step will be to determine the degree of resistance of seedlings of these older trees.

This block of seedlings was located within 200 feet of the cherry orchard where mazzard and mahaleb rootstocks were being tested and where the sweet cherry varieties suffered a heavy mortality. Those seedlings which had been seriously defoliated frequently were injured by low temperatures. None of the seedlings now remaining has shown any injury from low temperature.

Through the assistance of the Office of Plant Introduction, U. S. Department of Agriculture, a considerable planting of mazzards from central Europe was added to this test. These proved highly susceptible to leaf spot defoliation and to winter injury.

When the test of cherry stocks was first started, some commercial mahaleb seedlings were purchased and planted in a test nursery. These were not budded. From time to time they have been thinned out, removing any which showed any sign of winter injury. About 30 trees are still standing. These show a much wider degree of variability than any block of seedling mazzard grown at State College. Some of these mahalebs are dwarfish, some upright and vigorous; some have small leaves, others large leaves. It would seem that there is an excellent opportunity to select parent trees of mahaleb possessing desirable qualities which may be passed on in considerable degree to their seedlings.

In general, these tests of cherry rootstocks would indicate that it is not a question of mazzard versus mahaleb roots, but the performance of one group of seedlings from a known parent, or known strain, against another group of similar known origin. Also these results indicate that, with the cherry as with the apple, the performance of one scion root combination is not necessarily a guide to the performance of the same understock with a different scion.

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Importance of Parent Tree Selection in Studies of Seedling Rootstocks[1]

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The establishment of a Federal quarantine in 1931 which practically stopped the importation of understocks and the disruption of international commerce by two wars have brought about extensive changes in the sources of commercial rootstocks for American nurseries. Seeds from domestic varieties of apples have replaced French crab stocks. Pear seeds from western canneries have replaced French pear seeds. Much of the Mazzard seed comes from naturalized trees instead of from European imports. Mahaleb seeds are produced in limited amount from selected trees in the Pacific states. During this time also the source of peach pits has changed from naturalized trees in the southern Appalachians to the western canneries.

These changes in source have presented opportunities for the improvement of many, if not all, fruit understocks. The past quarter century of rootstock studies has developed principles and methods which can be of much service in seeking these improvements.

The ultimate goal in rootstock research is to find the clonal roots which are especially adapted to the particular scion variety to be used and to the soil and site selected for the orchard. Also these roots should be resistant to the common diseases and insects and produce trees of the desired size and productivity. Since, at present, we are not ready to recommend clonal stocks except for very limited use and since the nurseries are not ready to attempt the use of clones on a large scale, the next step would seem to be an improvement in the source of the seedling stocks now in use. Two lines of research at the Pennsylvania Experiment Station suggest the direction of this step.

About 1910 the U. S. Department of Agriculture secured specimens of several recognized varieties of French crabs. These varieties had been selected for their value in producing a desirable cider. In the commercial handling of French crab seeds these varieties lost their identity. When G. E. Yerkes of the Division of Horticultural Crops and Diseases began a study of the sources of seeds for American nursery understocks he grew seedlings from these French crab varieties to use in comparison with imported mixed French crab roots.

In 1930 the Pennsylvania Experiment Station, in cooperation with the Division of Horticultural Crops and Diseases, U. S. Department of Agriculture, planted two large blocks of apples on a considerable range of understocks in a commercial orchard near Chambersburg, Pennsylvania. In one of these blocks 10 York Imperial apple trees were on seedlings of Bonne de Feuilles and a similar number on Julien le Paulmier; both of these were French crab varieties which had been imported by the U. S. Department of Agriculture. By 1942 four of the first lot were dead, none of the second.

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There were also 10 Delicious trees on seedlings of D'Arroles, another French crab variety, and 11 on Black Ben Davis seedlings. By 1942, seven of the trees on D'Arroles roots were dead and only one of the trees on Black Ben Davis.

The following record is from an orchard of Gallia apples planted in Erie County in 1930:

Stock	Number Trees Planted	Number Trees Alive 1940	Average Circumference in 1940 (mm)
Bonne de Feuilles (*)	29	28	327 ± 3.9
Rouge de Landel (*)	13	8	312 ±11.5
Mixed domestic seedlings	26	23	386 ± 6.07

*French crab varieties.

The Malling rootstocks were selected by Hatton out of material much the same as the present French crab stock. The wide differences shown by the Malling types could, probably, be duplicated again by careful selection from the present commercial seedling stocks.

The variability in tree performance of varieties worked on roots propagated from seed taken from different French crabs of known origin raises a question of the desirability of using, as check trees in apple rootstock plantings, those commercially propagated on miscellaneous stock of unknown origin, even when such stock is called "French crab."

Yerkes and Anthony (1) reported before this Society in 1940 the results of growing several varieties of apples on seedlings from open pollinated seeds of known varieties. The increases in apple tree growth from the use of seedlings of certain named varieties were sufficiently large to justify much further study of selected seedling parents.

The results of a comparison of Mazzard and Mahaleb understocks for two sour cherries have been presented in another paper at this meeting. (2) The trees were planted in 1929 with Mazzard and Mahaleb stocks alternating at 20 foot intervals in the row with this alternation reversed in the next row. In general the roots in a single row represented two selections—one each of each species. Some of these selections were from native sources, some were imported. This planting plan made it possible to compare a single scion variety on two different Mazzard or Mahaleb roots, usually from widely different origins, with the trees to be compared standing diagonally across from each other. (The source of each selection is described in the paper by Clarke and Anthony).

When these trees were dug out in the fall of 1944, the tops were cut off at the crown of the roots and the entire top weighed. Table I shows the weight of Montmorency tree tops on Mahaleb roots from three different sources and gives the gain of one row over the adjacent row. Table II shows the difference in top weight of two different scion varieties on the same two Mahaleb understocks. Similar tables showing much the same kind of differences could have been prepared for the Mazzard roots. Table I shows that the source of the seeds has been as influential as the species in modifying tree growth and in

TABLE I—INFLUENCE OF SOURCE OF ROOTSTOCK ON WEIGHT OF TREE TOP. MONTMORENCY SOUR CHERRY. MAHALEB UNDERSTOCK. TREES PLANTED IN 1929; DUG OUT 1944. WEIGHT IN POUNDS

Row I Maryland Stock No. 493	Row J Imported Stock No. 749	J-J Gain or Loss	Row J Imported Stock No. 749	Row K Imported Stock No. 738	J-K Gain or Loss
321	181	140	181	37	144
438	214	224	214	128	86
309	217	92	217	156	61
366	153	213	153	93	60
225	109	116	109	61	48
221	291	-70	291	62	229
181	32	149	32	79	-47
Maryland Mahaleb better than imported Mahaleb. Odds 119 to 1			One imported stock better than another imported stock 45.7 to 1		

Table II the change from one scion variety to another has nearly reversed the effect of the understocks.

Research has reached the stage where advancement is usually due to refinement of the methods used. It would seem that the next refinement in fruit rootstock studies is to use seedlings of known and tested origin. Even though we know but one parent when we select open pollinated seeds from a single tree, the experiment at Pennsylvania State College justifies us in the expectation that parent trees can eventually be located whose seedlings will show a high degree of uniformity and which will prove compatible with the chief commercial varieties.

TABLE II—EFFECT OF DIFFERENCE IN SCION VARIETY ON THE INFLUENCE OF THE SAME ROOTSTOCKS. MONTMORENCY AND SAINT MEDARD ON MAHALEB ROOTS. WEIGHT OF TREE TOPS IN POUNDS

	Montmorency			Saint Medard		
Row	H	I	I-H	L	M	L-M
Source of Stock Nursery No.	Imported 736	Maryland 493		Maryland 493	Imported 736	
	40	321	281	481	505	− 24
	99	438	339	389	315	44
	122	309	187	261	447	−186
	180	366	186	347	370	− 23
	155	225	70	275	253	22
	Vacant	221		416	289	127
	Vacant	181		311	160	151
	Maryland Mahaleb superior to imported Mahaleb Odds 209 to 1			No significance difference Odds 1.75 to 1		

Commercially the selection of superior seed trees as a source of improved Mazzard roots has already been proved possible and highly profitable by at least two Pennsylvania nurseries.

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Performance of Clonal Understocks at The Pennsylvania State College[1]

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BEGINNING in 1912 two English agricultural experiment stations, one at East Malling, and one at Long Ashton, undertook to separate the different types of nursery stocks then in use in England and the continent of Europe. At that time nursery stocks for apple were classified into three general groups: Paradise, crab, and free. Paradise stocks composed a group of dwarfing stocks used mainly for trees on espaliers and cordons and in home grounds. Crab stocks were seedlings of crabapples and were reputed to be more hardy than other types. Free stocks were seedlings of commercial types of apples, chiefly cider apples. The station at East Malling undertook the work on Paradise stocks and later worked also on crab stocks, while the station at Long Ashton studied crab and free stocks.

The station at East Malling found that the stocks called Paradise were a heterogeneous group, the same name often being used for several different types. The group was divided into nine distinct types grown commonly in England, France, and Holland; and nine more types were later added from Germany (3, 4). These ranged from very shallow, fibrous-rooted types, which were very dwarfing, to large, deep-rooted types making practically standard trees. They were numbered from types 1 to 18 and typical specimens have since been propagated as clones; these are the types now known as the Malling stocks.

Similarly, the free and the crab stocks at the Long Ashton station also were found to be a heterogeneous group, and they were divided into three main types: shallow, fibrous-rooted stocks; intermediate stocks with some long roots and some fibrous roots; and stocks with long, deep roots with few lateral and no fibrous roots. These three types were later subdivided into nine classifications and were given the designation Class A to Class J (2). Some work was undertaken at Long Ashton in propagating as clones some of the more desirable specimens.

Later Hatton at East Malling divided a group of crab stocks into eight types according to the amount of fibrous roots and the depth of rooting (5). These have been designated as Crab A, B, C, etc. The types propagated as clones compose the material used in this country as Malling and Long Ashton stocks.

HISTORY OF ROOTSTOCK WORK AT THE PENNSYLVANIA STATE COLLEGE

The first shipment of Malling stocks was received by The Pennsylvania State College in 1921 for use in a carefully controlled fertilizer experiment in which the clone, Malling XII, was used as a stock for Stayman. The trees all made satisfactory growth. The work being

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done in England at this time so stimulated interest in Pennsylvania that a project on the improvement of rootstocks was initiated in 1922. While some work has been done with grape and with cherry stocks, the greater part of the work has been concerned with the propagation and the testing of apple clones, with special emphasis on the Malling stocks, and with determining desirable female parents for seedling stocks. The results of the trials with seedling stocks for apples have already been published (6).

STOCKS PLANTED AT PENNSYLVANIA STATE COLLEGE

Below are listed the stocks received by the Pennsylvania Agricultural Experiment Station and the orchard plantings involving the various stocks.

In general, these stocks were either lined out in the nursery for budding or placed in propagating beds or used in studies of methods of propagation. Parts of several shipments were sent to Mr. G. E. Yerkes, Bureau of Plant Industry, U. S. Department of Agriculture, to use in the nursery at Arlington Farm.

Stocks received from England. In 1920 through the cooperation of Dr. Hatton, a shipment of Malling XII stocks was received and in 1922 specimens of Malling I, VI, IX, X, XII, XIII, XV, XVI, and Crab A and Crab C were sent over together with a shipment from the Long Ashton Station of the University of Bristol containing types A10, B2, D1, E7, F12, G6 and G7. These were used to study methods of vegetative propagation. Later it was decided to test these stocks on a commerical scale using Stayman as the chief cion variety and in 1927 and 1930, from 100 to 600 each of the following were purchased from East Malling: I, II, IX, XII, XIII, XV, XVI, Crab A, Crab C, and Crab F. Also in 1927 a small shipment was secured from Long Ashton of E7, G6, G7 and G8.

In order to provide a basis for future correct identification Dr. Hatton sent over in 1930 six specimens of each of the Malling types then being propagated. Three specimens of each type were sent to Mr. Yerkes to be planted in Arlington Farm. The other three were planted in a permanent identification block at State College.

Stocks received from Geneva, New York. In 1937 through the help of Dr. Tukey, 200 specimens of Malling I and XVI and 90 of Malling XII were received and lined out for budding.

ORCHARD PLANTINGS AT STATE COLLEGE

In 1927 orchard No. 3 was started with 87 trees each of Stayman and Grimes Golden on U.S.D.A. T 200 stock, using as a comparison a block of Stayman trees purchased from a commercial nursery. In 1929 three more blocks were added of 87 trees each of Stayman on Malling XII, XIII, and XV. These trees were planted in blocks of three rows with the trees 20 x 20 and a space of 40 feet between blocks. In 1930 stocks of Malling I were planted 20 feet apart down the center of these 40 foot spaces. These stocks were grafted in place to Starking and Golden Delicious.

In 1934, fifty Northern Spys were planted in Orchard 1, using as stocks Malling II, X, XIII, XV, Crab A and Crab C and 18 Stayman on Crab A and C. At the same time the trees described later in Table I were also planted in this orchard.

In 1935 an addition to Orchard 3 was started with Rome Beauty on Malling II and XVI, and between 1939 and 1942 the following were planted: Starking, and Golden Delicious on Malling II, Northern Spy on U.S.D.A. 316, 323, 329, 1225, 1283, 227-2, 227-12, Rome Beauty on Malling XII, McIntosh on Malling XV, Stayman on Malling XVI.

In a study of stock — scion relations the problem of incompatibility is one of the first to be considered. To secure more information for Malling I, XII and XVI, two to four trees of a considerable list of varieties on each of these stocks were planted under orchard conditions from 1941 to 1945.

ORCHARD PLANTINGS IN OTHER AREAS OF PENNSYLVANIA

In 1929 and 1930 the following plantings were made in commercial orchards. The stocks were from those imported in 1927 and sent to Mr. Yerkes or were selections made by Mr. Yerkes and given U.S.D.A. numbers.

County	*Stock*	*Scion*	*Number*
Franklin	U. S. D. A. 316	Gallia Beauty	15
	U. S. D. A. 317	Starking	11
Delaware	Malling XII	Stayman	20
	U. S. D. A. 312	Stayman	20
	U. S. D. A. 317	Stayman	20
York	Malling XIII	Stayman	10
	Malling XV	Stayman	10
Eric	Malling XII	Stayman	45
	Malling XIII	Stayman	34
	Malling XV	Stayman	34
	U. S. D. A. 312	Stayman	13

An evaluation of the performance in Pennsylvania of each stock worked to the varieties previously indicated is given below.

THE MALLING ROOTSTOCKS — A RESUMÉ AND APPRAISAL OF THE ENGLISH CLONAL STOCKS

Malling I (Broad Leaf English Paradise):—As an unworked tree, this stock grows well for a few years. However, unworked specimens of Malling I at State College have been subject to winter injury of the trunk, and none has lived uninjured for more than 12 years. Injured trees usually sprout again from the crown. This stock is also quite subject to fire blight, and nursery trees have suffered severely from the disease. Older trees sometimes bear large, green fruits.

The stock propagates readily by layering. It has been worked to a number of varieties and has proven to be compatible in the nursery with all varieties with which it has been tested here.

In 1930, 87 Starking and 86 Golden Delicious were grafted in place on stocks of Malling I planted 2 weeks previously in orchard positions 20 feet apart. Two grafts of Starking failed. Up to 1944, 7 trees of Starking have died from undetermined causes, though most of these seemed to be due to stock failure. In the same period 11 Golden Delicious have died, apparently from failure of the stock. Most of the remaining trees have grown well, and, in fact, they are now remarkably uniform. The Golden Delicious began to bear in 1937 and have borne good crops since then. Growth is slowing up to a moderate degree. The Starking began to bear in 1939 and have had only light crops since then. They have shown no sign of being dwarfed. These surviving trees would be considered satisfactory.

Every other tree in this planting was pulled out with a tractor at the end of 10 years, and an excellent opportunity was presented to study the nature of the roots. Malling I showed a well-distributed, cone-shaped root system, the main lateral roots going down about 30 degrees from the horizontal. A few dead trees were pulled. In every case death occurred at the crown, the lower parts of the roots still being alive.

In 1937, from six to eleven grafts of each of the following varieties were made on Malling I: Baldwin, McIntosh, Stayman, Tomkins King, Williams Red, and York Imperial. Only one graft failure occurred, and all the trees grew well in the nursery. Three to four specimens of each variety were planted in the orchard. To date Baldwin and Williams Red give indication of being dwarfed, and McIntosh is slightly dwarfed. Stayman, Tomkins King, and York Imperial are growing normally.

Most of the trees on this stock have done well. However, the susceptibility of the stock to fire blight is a considerable nursery hazard; and its apparent lack of hardiness, as shown by the death both of unworked trees after a few years and of the roots of a number of the Starking and Golden Delicious worked on it, raises a serious question as to the desirability of this stock. We are no longer recommending it and have ceased further work with it.

Malling II (Doucin):—The three unworked trees of this stock in the identification block and specimen trees left in the older stock nurseries have grown well. The trees are narrow-upright and of moderate size. There is some tendency to sprout at the crown. They come into leaf at the middle of the period of leaf emergence in apples. These unworked trees have come into bearing early and produce small, greenish fruits, sometimes with a slight blush. The trees seem hardy. Temperatures as low as —30 degrees F have caused no winter injury. While other stocks have had serious attacks of fire blight, nearby stocks of Malling II have had only minor twig or blossom blight.

The stock propagates moderately well from mound and trench layers.

Malling II has been worked rather extensively at State College with a large number of varieties, and its performance has been quite variable. With some varieties it has done quite well, and with certain others it has done poorly.

This stock was included in a group of six English clonal stocks set out in 1934 in Orchard 1 as replacements in a variety block where a large number of trees had been removed several years before. The stocks were planted unworked, and were grafted the following spring to eight commercial varieties. A record of the number of survivors and of trunk circumference measurements of this block is given in Table I. As may be seen, the trees on Malling II performed reasonably well, except with Canada Red and Melba. It was most satisfactory with Cortland.

TABLE I—RECORD IN 1943 OF EIGHT VARIETIES ON SIX CLONAL STOCKS, PLANTING OF 1934 ORCHARD NO. 1, PENNSYLVANIA STATE COLLEGE

Variety	M II			M XII			M XV			L A G-6			L A G-7			L A G-8		
	Number of Trees Planted	Number Now Present	Average Trunk Circumference (Inches)	Number Trees Planted	Number Now Present	Average Trunk Circumference (Inches)	Number of Trees Planted	Number Now Present	Average Trunk Circumference (Inches)	Number Trees Planted	Number Now Present	Average Trunk Circumference (Inches)	Number of Trees Planted	Number Now Present	Average Trunk Circumference (Inches)	Number Trees Planted	Number Now Present	Average Trunk Circumference (Inches)
Red Rome (Cox)	3	3	7.33	5	3	11.08	3	3	8.42	3	1	6.75	3	2	7.12	3	3	10.92
Canada Red	2	2	6.00	2	2	7.00	3	3	7.08	3	2	8.50	3	3	8.75	3	3	8.58
Lobo	5	4	8.00	4	4	9.44	3	2	9.62	3	1	5.75	3	2	9.12	3	2	8.75
Melba	2	1	5.25	2	2	7.50	3	2	9.75	2	1	7.25	2	1	9.50	2	2	11.12
Delicious	3	3	6.50	4	4	8.12	4	4	8.75	3	2	6.50	3	3	7.00	4	2	7.62
Ohio Nonpareil	4	4	8.69	4	4	10.69	3	3	12.08	3	1	12.00	3	2	10.50	3	1	12.50
Cortland	8	7	10.07	5	5	10.00	5	5	9.05	5	4	7.91	5	4	8.69	5	3	10.33
Macoun	3	2	8.00	3	3	9.08	2	2	11.75	2	1	8.00	2	1	8.00	2	2	11.75
	30	26		29	27		26	24		24	13		24	18		25	18	

The combination of Rome Beauty on Malling II has been quite successful. The trees have been somewhat dwarfed, but have borne early and heavily. In 1935, a block of 60 trees of this combination was planted in Orchard 1, the trees being set 20 feet apart. In the first 3 years there were 6 casualties, some of which were caused by fire blight. In 1940, the total yield for the block was 26 bushels. In 1941, the crop was destroyed by frost. In 1942, the yield was 60 bushels; in 1943, 102 bushels; and in 1944, 164 bushels. These trees can all be picked from a low stepladder. In spite of considerable fire blight, the trees are vigorous, and the block is promising from a commercial standpoint.

Fourteen trees of the same lot were set out in vacancies in a Rome block in another orchard. Twelve still survive. In 1942, 10 of the trees had 1 or more bushels, four trees yielding over 2 bushels. The total crop was 19 bushels. In 1943, the crop was 17 bushels, and in 1944, 35 bushels.

Malling II has also been worked with a wide range of other commercial varieties. It has dwarfed practically all varieties. With some, the combination has been successful, with others their performance has been erratic, some specimens growing well, while others have done poorly. With a few varieties the trees have nearly all been very much dwarfed, shallow-rooted, and tending to lean over or sprawl on the ground. In most trees a large overgrowth at the graft union is evident.

Besides Cortland and Rome Beauty, Golden Delicious and York Imperial have done well in tests of a few years duration. Starking and Delicious have done moderately well, most trees being more or less dwarfed and bearing young, while a few trees have been shallow-rooted and have leaned badly. Many Stayman trees have failed to grow well on this stock, while others have been much dwarfed and have borne heavily. This combination is of doubtful value. Ohio Nonpareil, Macoun, Lobo, and Lowry are dwarfed on Malling II, but have borne well. Canada Red and Melba are shallow-rooted and of doubtful value. Northern Spy has remained small. In a planting of trees now 10 years old, only one tree in eight has borne any fruit. In the nursery, McIntosh on Malling II has remained very much stunted.

In summary, Malling II seems to be a good stock for some varieties, having a somewhat dwarfing effect and causing precocity in bearing. With other varieties the stock is not recommended.

Malling III (Holly-Leaf Crab).—The only specimens of this stock at State College are the three unworked individuals in the identification block planted in 1930. These have an abundance of burr knots. In one season all three trees were killed to the ground by fire blight. Since then they have sprouted from the crown. Some of these sprouts also have blighted. On account of its susceptibility to blight, no further work has been done with this stock.

Malling IV (Holstein Doucin).—The trees in the identification block are small and shrubby, and sucker badly from the crown. They bear fruits which are small, greenish, or occasionally with a slight red blush. No work has been undertaken to propagate or to work this stock.

Malling V (Doucin ameliore).—This stock grows as a shrub, suckering plentifully from the crown. The main trunks of the three trees in the identification block all died about the time that they were 10 years old. The stock may thus be lacking in hardiness. Borers have proved troublesome. At times the trees bear small, greenish apples.

The sprout growths from the crown root readily, and the stock is easily propagated. In 1943, Staymared was worked on this stock, and all the scions have grown well.

Malling VI (Nonsuch):—The only specimens at present at State College are the three in the identification block. These are sparse, open, small trees bearing moderately small, greenish fruits. The stock seems to root only moderately well under mound layering.

Malling VII (Old English Paradise):—The trees in the identification block are of medium size, sprouting somewhat from the crown. They bear profuse crops of small, russeted, yellow fruits. There has been some twig blight, but no serious attack. The sprouts root readily when mound layered. No attempt has been made to work this stock to commercial varieties.

Malling VIII (French Paradise):—In the identification block the trees are low shrubs, bearing large, yellow fruits of rather good flavor, somewhat sweet and ripening in late summer. No attempts have been made to propagate this stock.

Malling IX (Jaune de Metz) :—The unworked specimens of this stock grow as low bushes. The bark is yellowish, and the wood soft and brittle. Branches snap off rather easily when bent. Finger-size limbs are a favorite winter food of rabbits and mice, and the bushes often are eaten back to the ground line or snow line. The unworked trees bear crops of yellow, mildly sweet fruits of moderate size, ripening in the late summer.

Malling IX is quite subject to attacks from fire blight. The roots seem to be more than usually subject to damage from woolly aphis.

This stock is readily propagated by mound layering being one of the easiest of the Malling stocks to propagate in this way. As the trees come into leaf early, the work of propagation should be undertaken early in the season, as the newly separated plants do not thrive if they are handled after the leaves have begun to grow.

Trees worked on this stock are very much dwarfed. They often bear when 2 or 3 years old, and many are short-lived.

Although trees on this stock may make a very interesting back-yard plaything and may be suitable for espalier and cordon training, they are not recommended for orchard planting. For this reason no trees on this stock have been tested in the orchard. In 1931, 16 varieties were grafted on this stock in the nursery row. A total of 233 grafts were made, and 126 of them were successful. The only complete failures were 20 grafts each of Delicious and of Starking. The successful grafts were given wider spacing the following year and remained until dug out in 1940. Combinations with Stayman blood — Stayman, Staymared, and Turley Winesap — were apparently most successful and bore well for the size of the trees. York Imperial, Northern Spy, Smokehouse, and McIntosh were only moderately successful. None of these trees was staked, and many leaned badly or sprawled on the ground. In many trees the stock overgrew the scion.

Malling IX would seem to be especially valuable in preliminary testing of new varieties. The trees can be planted close and usually fruit quite early.

Malling X:—The three unworked trees in the identification block have made rather large trees with stout branches. They are later than the average in coming into leaf. Some of the larger limbs have been killed by fire blight. A few crops of green fruit below medium in size have been produced. The stock can be propagated fairly well by mound layering.

In 1934, 15 trees of Northern Spy on this stock were planted in a location in Orchard 1 to replace a row of trees which had been removed several years previously. The performance of these trees has been quite variable. Several appeared to have suffered from injury to the root system. It is probably wise to draw no conclusions from these trees until the roots have been studied.

Malling XII:—Unworked trees on this stock grow to fairly large size. They are quite late in coming into leaf. Of the three trees in the identification block, one failed to sprout after being girdled by mice. The other two attained good size. In one year a few small, green fruits were borne by one tree. One limb on one of these trees blighted in one season; this is the only record at State College of fire blight on this stock.

This stock is rather difficult to propagate, as it roots sparingly from mound or trench layers. However, the sprouts that do root usually grow well. When transplanted from the mound, they may require 2 years to become sufficiently well established to be ready for grafting. Grafts on established plants grow well. Roots of this stock may be formed by grafting long scions on nurse roots and planting them deeply. The scion then usually roots well and dominates the nurse root.

Malling XII has been used extensively as a stock for Stayman. In the first trial in which this combination was used, the trees were grown for 6 to 7 years in iron cylinders 5 feet across and 5½ feet deep in a carefully controlled fertilizer experiment (1). The stock did so well that it was again used with Stayman under the same conditions in a similar experiment running for 11 years, in which a study was made of the interrelation of soil organic matter and fertilizer nitrogen. Again the growth and fruiting of the trees were entirely satisfactory.

As previously indicated, three field plantings of Stayman on Malling XII, XIII, and XV were set out in 1929, one at State College, and two in Erie County. Smaller plantings in which Stayman was used on Malling XII were made also in several orchards in southern Pennsyl-

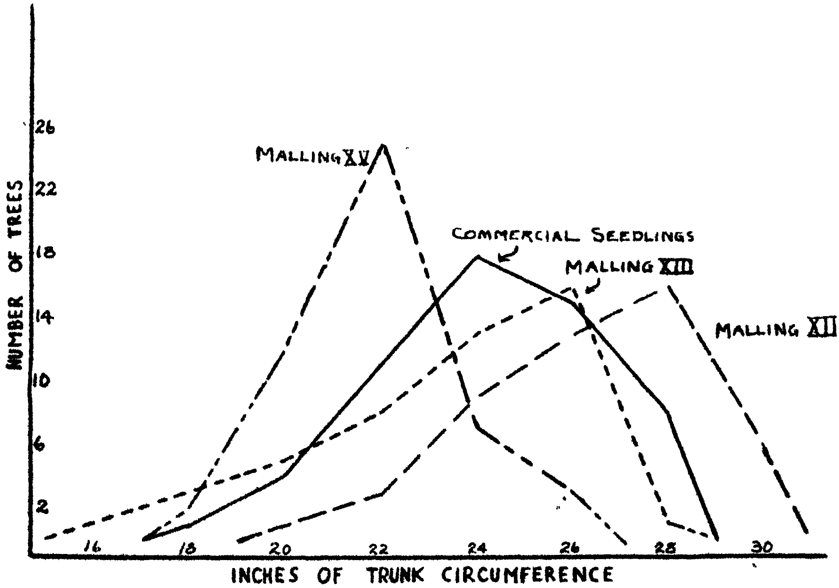

FIG. 1. Frequency curves of trunk circumferences of Stayman trees on four different stock types, Orchard No. 3, Pennsylvania State College. Commercial seedlings planted in 1927, measured in 1939, Malling stocks planted in 1929, measured in 1942

vania. In all these trials the combination of Stayman on Malling XII has been satisfactory.

In the planting in Orchard 3 at State College made in 1929 a block of Stayman on commercial seedlings planted 2 years previously in the same orchard has been used as a comparison. The frequency curve of the trunk circumference measurements of the trees on the four stock types is shown in Fig. 1. The trees on commercial seedlings were 1 year younger when measured. It will be seen that the trees on Malling XII have attained the largest size. The total yields per tree up to 1944 are as follows: commercial seedlings, 47 bushels; Malling XII, 21 bushels; Malling XIII, 20 bushels; and Malling XV, 18 bushels.

The greater yield of Stayman on commercial seedlings is due only partially to their greater age. In the plantings in Erie County the Stayman on Malling XII have outyielded those on other stocks, including some trees on French Crab seedlings and on Delicious seedlings.

The planting in Orchard 3 was made 20 feet apart. After eleven years of growth some of the filler trees were pulled out with a tractor, and an excellent opportunity was presented to study the root systems. In general, the roots were long, wide-spreading, little branched, and with few fibrous roots. They ranged laterally over a wide expanse, and some trees had two whorls of roots from a prominent tap root.

Malling XII was one of the six stocks used in a test with eight commercial varieties begun in 1934 in one of the State College orchards (see Table I). In this trial the trees have grown well, but have been slower to come into bearing than on any of the other stocks.

This stock has been used in more recent years with a wide range of other commercial varieties. No cases of incompatibility have been observed, and growth appears to be satisfactory with all varieties tested.

In general, Malling XII promises to be a very desirable stock. Although it is somewhat difficult to handle in the nursery, the high degree of survival in the orchard, the uniformity in growth, the wide range of compatibility, and the apparent resistance to fire blight are all valuable characteristics. To date it has been tested widely enough only with Stayman to receive an unqualified recommendation.

Malling XIII:—The unworked trees in the identification block have made vigorous growth and attained large size. They have borne crops of rather small, green fruits. Fire blight has been negligible.

Malling XIII roots readily from mound layers, and when lined out in the nursery, makes vigorous trees. When ready for planting in the orchard, the main roots are somewhat shallow and there is usually a mass of fibrous roots.

When the Stayman filler trees of the 1929 planting in Orchard 3 were pulled out at the age of 11 years and the roots examined, the root system of Malling XIII was less spreading than that of Malling XII. There were a few long laterals but many more fibrous roots, and side roots on the laterals were usually fibrous. The entire root system was so shallow that a large proportion of the roots came up with a layer of soil about 2 feet deep. In general, the soil in this area was from 3 to 8 feet deep.

At State College severe droughts occurred during the summers of 1929 and 1930. From 1930 to 1932 a total of 11 out of 87 Stayman on Malling XIII from the 1929 planting died, evidently from the effects of the dry weather. No other stocks in this block were seriously affected. Several other trees on Malling XIII were checked in growth following a severe drought in 1939. These trees were in spots where the soil is thinnest — mostly about 3 feet.

Where trees have been unaffected by drought, growth and fruiting have been satisfactory. On account of drought injury, considerable variation exists in the size of the trees on this stock, as may be seen by referring to the frequency curve of trunk circumferences (see Fig. 1).

No incompatibility was observed when the following varieties were grown on Malling XIII for several years in the nursery row: York Imperial, Rome Beauty, Jonathan, Baldwin, Delicious, Golden Delicious, Northern Spy, and Winter Banana.

In the plantings in Erie County and in southern Pennsylvania, there has been a high mortality of Stayman on Malling XIII. In some plantings more than half the trees have died. This stock is evidently not adapted to dry soils. On account of its high mortality and lack of resistance to drought, this stock is not recommended for Pennsylvania.

Malling XV.—Unworked trees of Malling XV are vigorous and attain large size. They bear crops of small, greenish fruits. This stock is very late in coming into leaf in the spring, the buds beginning to break about the time most varieties are in full bloom. There is no evidence that this lateness of starting in the spring influences the time of the opening of leaf buds in any of the varieties which have been worked on this stock. However, the stock can be handled much later in the spring. It is hardy, having shown no injury from severe winters, and it has been free from fire blight.

Malling XV is one of the most difficult to propagate of any of the Malling stocks. It roots sparingly in trench or mound layers, but when rooted it grows well. It can be propagated with reasonable success by bench grafting a long scion on a nurse root and planting it deeply. The scion roots usually dominate the nurse roots.

When the filler Staymans were pulled out in the 1929 planting at State College, those on Malling XV were so deeply and firmly rooted that hardly a tree pulled out cleanly; many broke off at the ground, or only a few laterals pulled out. As far as could be observed, the roots were long with a few fibrous roots, and they ranged widely and deeply.

This stock has been tested extensively with Stayman in comparison with Malling XII and XIII. In the State College orchard and in plantings through the state, the trees on Malling XV have been smaller than those on Malling XII, but their yields have been only slightly less. They have grown uniformly, and there have been very few casualties.

Malling XV was one of the six stocks used with eight commercial varieties in an orchard planting at State College in 1934. A reference to Table I will show that the mortality on this stock has been negligible and that growth has been as good as or better than the average.

The trees have already begun to bear. A younger planting of McIntosh on this stock is growing well, although the trees were somewhat slow in becoming established.

This stock has not been widely enough tested to make it seem wise to pass judgment on it as yet. In spite of difficulties in propagation, it seems promising because of freedom from blight, hardiness, vigor, and uniformity. It seems to dwarf Stayman slightly, but with other varieties tested for fewer years, its performance has been entirely satisfactory.

Malling XVI:—Unworked specimens of this stock make trees of only moderate size. They possess large numbers of burr knots. Sometimes limbs on unworked trees have died, but the cause of death has been unknown. The smaller twigs and spurs of this stock have shown considerable fire blight, but the cankers have seldom extended into older wood, so that the blight has not been serious.

Malling XVI is later in coming into leaf in the spring than any other stock or variety at State College. It is usually several days later than Malling XV. Most varieties have finished blooming before leaves appear on XVI. Blossoms sometimes appear about with those of Northern Spy and before the leaf buds break. Fruits are small and greenish.

This is one of the easiest stocks to propagate. It roots readily in the mound layer. Older trees cut off at or below the ground line sprout well, and the sprouts root when mounded. The use of a nurse root in bench grafting long scions also is a successful method of propagation.

This variety was not used in experimental work until 1939. Since then it has been used rather extensively as a stock for a wide range of commercial varieties. It has proven to be compatible with practically all of them, though there is some indication that many trees will be somewhat dwarfed, and it may induce precocity of bearing in some trees. It has not yet been used long enough here for judgment to be passed on it at this time.

Malling XVII:—This stock is represented at State College by only two specimens in the identification block. These are small and bushy, and with many burr knots. No work has been performed in its propagation or testing with varieties.

MALLING CRAB STOCKS

At East Malling eight types of stocks were classified from a group of crab stocks imported from the continent of Europe (5). The three most vigorous in this series, Crab A, Crab C, and Crab F, of which typical specimens had been propagated as clones, have been tested at State College.

Crab A:—Unworked trees of this stock are of moderate size and good vigor. They bear greenish fruits of small to medium size. They have been subject to fire blight, the infections sometimes killing back the main limbs several feet.

Five specimens of Northern Spy and three of Stayman were planted in Orchard 1 in 1934 and 1935. The Stayman trees show considerable variability, while the Northern Spy trees are normal.

Under conditions at State College, this stock shows no special merit which would suggest the value of further trial.

Crab C:—Unworked trees of this stock are large and vigorous and have borne crops of green fruits of small to medium size. They have not been subject to fire blight.

In the nursery this stock has rooted moderately well in mound layers, but it is slower in growth than most of the other Malling stocks.

Crab C has been used as a stock for Stayman and Northern Spy in the 1934 and '35 planting in Orchard 1. Both varieties have made normal growth.

Crab C seems to have sufficient promise to justify further trial.

Crab F:—The unworked specimens of Crab F have made large, vigorous trees. They have borne fruits of medium size, greenish, and often with a red blush. Unfortunately, the trees are quite subject to fire blight, and they have killed back badly in years in which blight was serious.

Crab F propagates well from mound layers and from nurse-rooted bench grafts. On account of the ravages of fire blight, very little work has been done with it as a stock.

Long Ashton Stocks

Four types of free stocks propagated as clones by the station at Long Ashton, England, have been given rather extensive trial at State College.

Long Ashton E-7:—Unworked specimens of this type have made large, compact trees with many limbs. The lower limbs are quite thorny. It has shown some fire blight infections, but these have not been serious.

This stock roots very easily from mound layers. It comes into leaf very early in the spring, and rooted shoots must be removed and planted out very early to insure a successful stand.

This stock has been worked with two varieties in the nursery. Only two Delicious scions out of 12 made a union, and subsequent growth was feeble. Ohio Nonpareil scions united to make a 50 per cent stand, and their subsequent growth was good.

The extreme thorniness of this stock makes it mean to handle, and the suggestion that it may be incompatible with some commercial varieties will probably limit any further work with it.

Long Ashton G-6:—This stock when unworked makes vigorous, upright trees with dense foliage. It bears medium to large, green fruits with a good flavor, and tart enough to make good cooking apples.

This was one of the stocks used in the 1934 planting in Orchard 1, when six types of stocks were worked to eight commercial varieties (see Table I). It has proven to be the poorest of these six stocks, having more failures than any other stock and producing trees with nearly all the scion varieties that are more or less dwarfed and well down the list in vigor. Some of these trees have come into early bearing.

Because of its poor orchard record, this stock has not been used in more recent experimental work.

Long Ashton G–7:—Unworked specimens of this stock make dense trees of medium size. Some twig blight has occurred. This is one of the easiest stocks to propagate in mound or trench layers.

G–7 was also included in the orchard planting of 1934 in Orchard 1. Trees of the eight scion varieties on G–7 are about an average of the block in size and vigor, and very few failures have occurred. Many of these trees have been precocious in bearing.

It will be some years before judgment can be passed on the orchard performance of this stock. Some further work with it may be justified.

Long Ashton G–8:—Unworked trees of G–8 have been medium in size and rather dense and compact. The fruits have been green and about the size of golf balls.

G–8 roots sparingly from mound layers, being one of the most difficult stocks to propagate. However, when once rooted, the nursery trees grow well and are of above average vigor.

In the orchard planting of 1934 with G–6 and G–7 and with three Malling stocks worked to eight commercial varieties, the trees on G–8 are among the largest in the group. However, the mortality has been next to the highest. Many of the trees are now in bearing.

Because of the conflicting record of a high death rate but vigorous trees, judgment on this stock must be deferred until after further study.

CERTAIN OF THE STOCKS ORIGINATED BY THE UNITED STATES DEPARTMENT OF AGRICULTURE

U. S. D. A. T–200. This stock was selected in 1921 by Mr. G. E. Yerkes, Bureau of Plant Industry, U. S. D. A., from a shipment of 5,000 one-year commercial nursery seedlings grown at Toppenish, Washington. It was chosen because in the nursery it approached the ideal in size, conformation, and distribution of its roots; and it was then propagated as a clone for experimental studies in the uniformity of clonal stocks in comparison with those on seedling stocks. One of the experimental blocks using this stock was planted at State College in 1927 in Orchard 3 (*7*).

In this experimental block 87 Stayman on T–200 and 87 Grimes Golden on T–200 were planted and compared with 116 Stayman on commercial nursery seedlings. These seedlings were chosen from a large group for their uniformity. All trees were 1 year old when planted. An account of the behavior of the two blocks of Stayman over the first 11 years has already been given (*7*).

All trees were planted 20 feet apart. In 1935 the Stayman on commercial seedlings were crowding so much that every other tree in each row was pulled out, and in 1939 the block was further thinned to make the trees stand 40 feet apart. The Stayman and Grimes Golden on T–200 roots were not thinned until 1939, when they were thinned to stand 20 by 40; and in 1942 they were further thinned to 40 by 40.

The trees on commercial seedlings have grown well and are quite vigorous. For commercial trees they have been surprisingly uniform. One tree acted as a true dwarf, being about two-thirds of normal size and bearing heavy crops of fruit at an early age. Another tree, normal up to 1940, died that year from root failure.

The Stayman trees on T–200 showed signs of being dwarfed by the third year after planting. They bore small crops of fruit in 1930 and 1931, while the commercial trees bore only a few scattered apples. At first the trees on T–200 were rather uniform, but after 10 years of growth, certain trees began to show more vigor than the rest. When some of the trees were pulled out in 1939, a study of the roots showed that these trees had become scion rooted. Some of the trees now standing are clearly scion rooted.

In contrast to the marked dwarfing effect on the Stayman, the stock T–200 has had little dwarfing effect on the Grimes Golden. Root studies in 1939 showed some scion rooting on these trees also, but they are still uniform in size and have grown and fruited as normal trees.

The root systems of the trees that were pulled out were unusual. The T–200 stocks that had been worked to Stayman had overgrown, swollen butts with the overgrowth terminating abruptly at 1½ to 2 feet. For some unaccountable reason the lower ends of these overgrown butts nearly all pointed toward the east or north-east. Many small laterals extended out from these butts, and some trees had a few well developed side roots. On trees where scion roots were well developed, the T–200 roots were somewhat dwarfed.

The Grimes Golden on T–200 showed some scion rooting, but the scion roots were smaller and fewer than with Stayman. The shape of T–200 roots under the Grimes was similar to that under Stayman, but the roots were larger and better developed.

The differential behavior of the Stayman and the Grimes Golden on this one stock shows clearly the necessity of testing every variety on a stock before recommendations can be made about its stock-scion relations. Mr. Yerkes has indicated that the stock was propagated only for certain experimental purposes; and as these purposes have been fulfilled, it would seem best to drop any further work with it.

OTHER STOCKS FROM THE U. S. DEPARTMENT OF AGRICULTURE

Several other clonal stocks besides T–200 have been used in orchard plantings in Pennsylvania.

U. S. D. A. 312, a clone from a seedling of Vermont origin, has been used, worked to Stayman in two orchards, one in Erie County and the other in Delaware County. It has given satisfactory performance in both places. In the orchard in Erie County, which was planted in 1929, it has been compared with Malling XII, XIII, and XV, and with seedling stocks derived from Delicious seed, and with French Crab seedlings. Twelve to thirteen trees of each stock were used in the comparison. Trees on U. S. D. A. 312 have made more growth than trees on both the stocks from seedling sources, about as much growth as those on Malling XV, but less than those on Malling XII.

U. S. D. A. 316 is another clone progagated from a seedling of Vermont origin. Worked to Gallia Beauty, it was planted in 1930 in an orchard in southern Pennsylvania. After 12 years of growth, of 15 trees planted, 3 had been replaced and 4 more were reported as being very weak. Eight trees of Northrn Spy planted on this stock in a State College orchard all have grown well.

. U. S. D. A. 317, another clone propagated from a Vermont seedling, has been used with Starking in an orchard block planted in 1930 in southern Pennsylvania. After 12 years of growth, out of 11 trees planted, 3 had been replaced, and one more was reported to be nearly dead.

From 7 to 8 trees each of Northern Spy on U. S. D. A. 316, 323, 329, 1225, 1283, 227-2, and 227-12 were planted in Orchard 3 in State College in 1939, with French Crab seedlings for comparison. All these trees have made good growth, the French Crab seedlings having given the poorest performance. Several trees on the stocks U. S. D. A. 323 and 329 lean rather badly. At the present time it is too early to pass judgment on this block.

The tests with the stocks received from the United States Department of Agriculture have not been extensive enough in Pennsylvania for any definite conclusions to have been reached regarding their value.

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Behavior of Apple Varieties on Certain Clonal Stocks

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A SEARCH for apple stocks resistant to woolly aphis, hardy to cold, and readily propagated as clones was begun in 1922. After a large number of seedlings from different sources had been grown in the nursery at Arlington Farm, Virginia, individual seedlings exhibiting unusual vigor and well-formed root systems were selected for clonal propagation. The clones were then evaluated on the basis of resistance to woolly aphis, readiness of multiplication, winter hardiness, and congeniality as stocks for commercial apple varieties. Some of these clones have been sent to other experiment stations for trial, and preliminary reports of their performance have been made (4, 5, 8, 9, 10, 11, 12, 13, 14). The results of four series of field plantings at Beltsville, Maryland, together with some essential background information on the origin of the clonal stocks, are summarized in this report.

SOURCES AND CHARACTERISTICS OF THE CLONAL STOCKS

The clones were propagated from the original selected seedlings by root cuttings as a convenient means to produce the limited numbers needed for trial. The offspring from root cuttings usually were more uniform in size than those from layers. Layering, however, might be a more practical method of propagating most of them. The rate of increase by root cuttings varied greatly among the different clones.

Much of the early work of selecting and testing the stocks was done at the Arlington Farm nursery, near the District of Columbia, where heavy infestations of woolly aphis, especially when the summers were rather dry, afforded opportunities to observe resistance to aphis infestation under field conditions that were favorable for woolly-aphis development. Infestation was further promoted by planting aphis-infested seedlings close to the test plants. To supplement such natural infestation, many of the clonal plants were inoculated by placing small chips of apple wood, on which colonies of aphis were feeding, under flaps cut in the bark near the ground line.

The cold-hardiness of the more promising stock clones was tested in the laboratory by Dr. Neil W. Stuart (6). The method (7) consists in freezing dormant pieces of roots under controlled conditions. After thawing, the samples are placed in distilled water and the release of electrolytes measured by electrical conductivity. The exosmosis of the electrolytes from the frozen tissue is considered to be proportional to the amount of freezing injury. Clones Nos. 1224, 1225, 1226, 1227, 1256, and 1263 exhibited exceptional cold-hardiness in these laboratory tests. Somewhat less hardy than the clones just named, but in most cases more hardy than French Crab, were clones 316, 317, and 323.

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[1] The experimental work prior to 1940 was conducted by G. E. Yerkes. During 1943-44-45 W. W. Aldrich obtained the growth data of Series III and IV and helped with the interpretation of the results. Drs. F. E. Gardner, P. C. Marth, and C. F. Swingle assisted in certain phases of the investigations.

The clones selected for special study were designated by number and include the following numbers:

Clone 227:—The original of this clone attracted attention in a planting of Northern Spy seedlings grown from seed obtained in the varietal orchard in 1923. It was the most robust of all and on trial was found to be highly resistant to woolly aphis and easy to propagate. However, it was soon discovered that many scion varieties failed to grow on it. In the fall of 1927 buds of 10 varieties were set on 1-year-old trees of clone 227. At the end of 18 months the trees budded to Baldwin, Northern Spy, Rome Beauty, Winesap, and Yellow Newtown were all dead, whereas those budded to Delicious, Jonathan, McIntosh, Smokehouse, and Yellow Transparent were still growing satisfactorily. In subsequent years some propagations of Winesap and of Yellow Newtown on this stock grew satisfactorily for many years, thus providing apparent contradictions to the first results. In tests at other experiment stations, McIntosh has not always been compatible with clone 227 (3, 11), and it has been suggested (4, 5) that the inconsistencies were related to the sources of the McIntosh budwood.

Clones 227–2 and 227–12:—These clones were selected from seedlings of 227.

Clones 316 and 323:—These clones originated from seed obtained in 1921 from a commercial source near Waterville, Vermont. This seed was said to be the product of seedling trees, the naturalized offspring of local orchard varieties. Formerly seed from such naturalized trees, called "Vermont Crab," was used in considerable amounts and was preferred by some nurserymen for producing seedlings for stocks. From several hundred seedlings grown in our nursery, a few individuals were selected for vegetative propagation. Although 316 and 323 are not fully resistant to woolly aphis, they compare quite favorably with other stocks for Gallia Beauty, Starking, Stayman Winesap, and York Imperial in the cooperative test orchard at Kearneysville, West Virginia, set out in 1933. Several progress reports have been made regarding this experimental orchard (8, 9, 10, 13, 14).

Clone 329:—This clone was selected from commercial seedlings grown from seed collected from local orchards at Owatonna, Minnesota, by the Clinton Falls Nursery Company. It is not particularly resistant to woolly aphis. Although from a northern source and somewhat hardier than French Crab, it is not regarded as outstanding in tolerance to cold.

In 1930, T. J. Maney, of the Iowa Agricultural Experiment Station, sent us 300 1-year-old seedlings from seed produced by a tree designated as Ames 570 (Brier Sweet x Mercer), with the information that seedlings from this tree had indicated promise as commercial stocks (2). In our nursery many of the seedlings, like most of those from other sources, were attacked severely by woolly aphis, but several were not affected. Clones 1223 to 1227 were propagated from selections of these resistant individuals. Although aphis galls have since been found on them, the attacks have been light. While all five have proved congenial with the varieties that have been budded on them, the growth on 1225 has been above the average for several varieties and it is a little easier to propagate vegetatively than the others. This group is of special interest because its ancestry includes *Malus ioensis* from Mercer (1) as well as the cultivated apple. Incompatibility of *M. ioensis* with orchard varieties has been observed in our nursery, but no such tendency has been shown by the group from this cross. The resistance to woolly aphis in this case may be derived from *M. ioensis.*

Several seedlings of Fameuse were selected and clonally propagated in 1930, but of these the only one retained was clone 1232. It is not conspicuously resistant to aphis, but in early tests showed some resistance to cold. The growth of varieties budded on it has been somewhat slower than when budded on several others.

Clones 1250 to 1309, inclusive:—These clones were selected in 1930 and 1931 from several thousand seedlings quite variable in size and root development, grown from open-pollinated seed of Northern Spy. Apparently they have considerable resistance to woolly aphis, and certain ones, 1256 and 1263, are quite cold-resistant. The rate of increase from root cuttings and layers has been slower from these two clones than from many of the others.

Successive planting of trees on these stocks are discussed under the headings Series I, II, III, and IV.

Series I:—In the fall of 1932, buds of 114 varieties were set on 1-year-old trees of clone 227. After being grown in the nursery 2 years, all trees still alive in the spring of 1935 were set out in close planting at the Plant Industry Station, Beltsville, Maryland. The four to eight trees of each scion variety were planted together and pruned rather heavily each year. Notes on survival and tree condition were taken in 1945 after a 10-year period, and the varieties classified into six groups according to their growth behavior. The number or name following certain variety names refers to the designation originally used for distinguishing apparent fruit-color mutations of these varieties.

Group 1:—The 39 scion varieties on clone 227 that grew satisfactorily during the 10-year period were: Carlton, Chelan, Chenango, Collins, Cortland, Delicious-25 (Seaton), Delicious-27, Delicious-28, Fallawater, Gilbert, Golden Delicious, Jonathan Joyce, McIntosh, McIntosh-30 (Striped), Medina, Melba, Milton, Missouri Pippin, Northern Spy, Ogden, Opalescent, Perkins, Peter, Redsauce, Smokehouse, Stark-4, Summer Rambo, Tioga, Transcendent (crabapple), Wagener, Whitney, Wilson Redjune, Winesap-23, Winesap-32 (Seeando Winesap), Winesap 19, Winter Bananam, Wolf River, and Young America.

Group 2:—The 15 varieties of which one or two trees in each test lot died of unknown cause during the test period, but the remainder grew satisfactorily, were: Bloomfield, Delicious, Delicious 1–16, Gano, Henry Clay, Hume, Ingram, Keetosh, Lowland Raspberry, Lodi, Lowry, Macoun, McIntosh-Blush, Mother, and Willowtwig. These varieties may have been as congenial on clone 227 as those of Group 1.

Group 3:—All trees of each of the following six varieties made much less growth than those in Group 1: Lawver, Orange, Rome Beauty, Winesap, and Yellow Newtown.

Group 4:—20 varieties that appeared normal during the 2 years in the nursery but died the third season after budding (first year in final planting) are: Blackjon Jonathan, Duchess-Double Red, Duchess-Red, Esopus Spitzenburg, Fameuse, Hubbardston, Kinnard, Magnet, Martha, Red Astrachan, Rome Beauty-Dark Red, Scarlet Pippin, Stayman Winesap, Stayman Winesap-13. Stella, Tompkins King, Turley, Wealthy, and Winesap-20 (Red) and Winter Pearmain.

Group 5:—27 varieties that made normal growth the first year in the nursery but died the second season are: Baldwin, Baldwin-Dark Red, Benoni, Blaxtayman, Lobo, Nero, Northern Spy-Red, Rome Beauty-10, Rome Beauty-17, Rome Beauty-Leake, Roxbury Russet, Stark, Starr, Stark-Red, Staymared, Summer Queen, Tompkins King-Red, Twenty Ounce, Winesap-24, and Yellow Bellflower.

Group 6:—Seven varieties that made little growth and died in the nursery during the first season after budding are: Gravenstein, Jefferis, Mammoth Beauty, Rome Beauty-12, Stump, Williams, and Winesap-21.

Since mouse injury or mechanical breakage may have contributed rather largely to the death of trees of varieties listed in Group 2, there may be no significance to the separation of the varieties in this group from those in Group 1. Group 3, however, is noteworthy, particularly because of the survival of these trees of Rome Beauty, Winesap, and Yellow Newtown constitutes another apparent inconsistency in behavior of certain varieties on clone 227. Whether a variety is in Group 4, 5, or 6 may have been due to environmental factors in the nursery rather than to any specific relation between the variety and clone 227. However, the results of Series I emphasize that, with the budwood used, a large number of varieties or variety strains did not survive on clone 227, that a few survived but were greatly dwarfed, and that others made satisfactory growth.

Series II:—One-year-old plants of several clonal stocks were set out in the spring of 1934 together with Grade 1, branch-rooted French Crab seedlings purchased at Toppenish, Washington. These were budded during the summer to Starking, Stayman Winesap, and York Imperial. In April 1936 the resulting trees were transplanted to a low, tile-drained area of sassafras loam and spaced 5.5 x 12 feet apart. Most of the stock-scion combinations were represented by 16 trees, but some by only four to eight trees. Where there were eight or more trees of each stock-scion combination, half of the trees were planted at one location and the other half at another. Trees on clone 323 were planted in alternate pairs in every third row throughout the planting for a measure of soil variability. All the trees of each scion variety were planted together.

The final measure of growth was obtained in the fall of 1941 by pulling all the trees and weighing the top of each. Variations in growth between duplicate lots of each scion-stock combination were so great for the scion varieties Starking and Stayman Winesap that, when the data were subjected to analysis of variance, the F value was considerably less than that required for significant difference between top weights, as influenced by stock effects. However, in the case of the scion variety York Imperial, not only was variation between duplicate lots relatively less than with the other two varieties, but there were also much larger differences in weight of top between some of the stocks. The average weight of the tops of each scion-stock combination is given in Table I.

TABLE I—EFFECT OF DIFFERENT CLONAL STOCKS ON THE AVERAGE WEIGHT OF THE TOPS OF TREES PLANTED IN APRIL, 1934 AND PULLED IN THE FALL OF 1941

Stock	Average Weight Per Tree of Tops of Each Scion Variety in Fall of 1941		
	Starking (Pounds)	Stayman Winesap (Pounds)	York Imperial (Pounds)
323	24	25	46†
French Crab Seedling	17	16	30
227	36	Died	Died
316	21	16	43
317	14	18	39
329	18	34	46†
1223	–	24	48†
1224	29	20	61*
1225	28	32	61††
1226	28	26	58††
1227	19	22	11‡‡
1232	12	11	37
1240	22	21	34
1241	23	–	53††
1244	16	4*	32
1249	26	20	32*
1251	18	21	46†
1256	26	19	22
1258	15	18	29
1260	14*	–	–
1263	25	21	47†
1267	15	16	11‡‡
1268	21	10	29
1269	10	10	32*
1270	–	–	11‡‡
1271	22	19	14*
1272	13	12	42
1273	21*	9	60*
1275	23	16	37
1283	16	13	8*
1286	20*	13	6*
1288	25	21	12‡
1290	-	30*	10
1291	16	15	6‡‡
1294	22	17	37
1295	–	14	–
1296	29*	18*	–
1297	15*	32	49††
1298	11	9	30
1299	5*	–	–
1300	16	19	16
1302	–	15	52*
1303	22	12	8‡‡
1304	25	16	1*
1306	19*	12	–
1309	20	12	36
			L. S. D. at 19:1 = 14
			L. S. D. at 99:1 = 16

*Specific scion-stock combination at only one location and therefore not included in statistical analysis of data.

† and†† = Top weight greater than that for clone 323, by odds of 19:1 and 99:1, respectively.

‡ and ‡‡ = Top weight less than that for clone 323, by odds of 19:1 and 99:1, respectively.

Among the York Imperial trees in this rather poorly drained soil, those on clones 1224, 1225, 1226, 1241, and 1297 were considerably larger than the trees on French Crab seedlings, with odds for significance of 99: 1. In case of clone 1225, the tops were larger (odds 19: 1) than those on 316, 323, 329, 1251, and 1263. Trees on 323, 329, 1223, 1251, and 1263 were larger than those on French Crab by odds of 19: 1. On the other hand, the York Imperial trees on 1227, 1267, 1270, 1291, and 1303 were dwarfed, as compared with those on French Crab, with odds of 99: 1. In those cases where the specific scion-stock combination was planted in only one location in the field [indicated in Table I by "(*)"], the weight data were not included in the statistical analysis, and any indicated differences are considered as being suggestive only.

Series III:—The varieties Rome Beauty, McIntosh, Winesap, Williams, and Wealthy were budded on 16 clonal stocks and also on seedlings of Delicious and of clone 227. In April 1937 these were set out adjacent to the plants in Series II. There were four to eight trees in each stock-scion combination in both the north and south halves of the area used. In the south half the trees in general made poorer growth than the replicates in the north half, apparently as a result of the soil being more shallow in the south half.

In October 1944 each tree was visually rated as to size, on a scale of 1 to 5, 1 being extremely small and 5 the maximum size for the variety top. The average rating of trees of each scion-stock combination, based on the trees in the north half of the planting only, is given in Table II.

TABLE II—EFFECT OF DIFFERENT CLONAL STOCKS ON THE GROWTH OF APPLE TREES PLANTED IN APRIL, 1937 AND RATED IN OCTOBER, 1944 (SERIES III)

Stock	Average Rating* of Each Rootstock With Each Scion Top				
	Wealthy	Williams	Winesap	McIntosh	Rome Beauty
323	4.1	4.9	4.8	4.9	4.9
Delicious Seedlings	4.0	3.0†	4.0	4.8	5.0
316	3.8	4.0	4.0	5.0	5.0
329	3.5†	4.0	3.3†	5.0	4.5
1223	4.3	4.8	5.0	4.8	4.8
1224	4.0	4.8	4.5	4.8	4.5
1225	4.8	4.5	5.0	5.0	4.5
1226	4.3	4.8	5.0	5.0	4.8
1232	4.0	4.0	2.7**	5.0	3.0†
1256	3.0**	4.8	3.5†	5.0	2.0**
1263	4.3	4.8	5.0	4.8	4.8
1272	3.5†	3.3†	3.5†	4.5	3.5†
1283	1.0**	2.8**	2.0**	4.5	1.0†
1300	2.3	3.0	4.3	4.5	2.0†
1302	5.0	5.0	4.5	5.0	4.0
1309	4.0	4.8	4.8	5.0	4.0
227-2	2.0	3.3**	4.0	2.5**	2.0†
Clone 227 Seedlings	Died	Died	4.5	4.3	1.7**

*Rated visually by two men.
5 = Largest trees of variety
4 = Slightly smaller top and trunk than "5"
3 = Conspicuously smaller than "4"
2 = Relatively small tree
1 = Extremely small (not over 4 feet high)
** = All trees relatively small
† = One or two trees relatively large, but others small

In cases where the average rating was low, but one or two trees of that scion-stock combination were relatively large, the average rating is questioned, because of the likelihood that some factor other than stock had been responsible for the relatively small trees. However, in cases where the average rating was low and all the trees of that scion-stock combination were relatively small, the average rating is considered a measure of the influence of the stock. Clones 323, 1223, 1224, 1225, 1226, 1263, and 1302, as well as Delicious seedlings, produced fairly satisfactory trees of all five of the scion varieties, with average ratings varying from 4.0 to 5.0. The only exception was Williams on Delicious seedlings, in which case some of the trees were relatively small. Seven of the clones, however, as well as seedlings of 227, apparently dwarfed one or more of the scion varieties (average ratings of 3.3 or less). In the case of McIntosh tops, only those trees on 227–2 were dwarfed; whereas among Rome Beauty trees, those on 1256, 1283, and 1300 and on seedlings of 227 were greatly dwarfed. Winesap seemed to be definitely dwarfed on 1232 and 1283; Williams on 1283, 1300, and 227–2; and Wealthy on 1256, 1283, 1300, and 227–2 (Table II).

Series IV:—An additional lot of trees, with Baldwin, Yellow Transparent, Jonathan, and Northern Spy budded on 9 stocks, was planted in the spring of 1939. The experimental design provided 4 replications of randomized 4-tree groups, with trees on clone 323 stocks planted adjoining each group. This arrangement permitted a direct comparison of tree size on each stock with those on clone 323.

In October 1944 the relative size of the trees was estimated by measuring the trunk circumference and calculating the trunk cross-sectional area. The average trunk cross section for each of the four-tree groups of each scion-stock combination was computed. The difference in cross-sectional area between each such group average and the average for the adjacent group on clone 323 was then determined and the statistical significance of these differences found by analysis of variance. A summary of these results is given in Table III.

TABLE III—EFFECT OF DIFFERENT STOCKS ON THE GROWTH OF APPLE TREES PLANTED IN APRIL, 1939 AND MEASURED IN OCTOBER, 1944 SERIES IV)

Stock	Difference in Average Cross-Sectional Area of Trunk Between Trees on Each of Eight Stocks and That of Adjacent Trees on the 323 Stock, for Each Scion Variety (cm²)			
	Baldwin	Yellow Transparent	Jonathan	Northern Spy
French Crab	–4.4	–2.8	–5.4	–3.6
316	+0.6	+1.2	–1.0	+3.8
329	+0.2	+4.0	–2.4	–3.4
1225	–1.1	+6.1	+11.5	+6.4
1226	+2.6	+3.9	+ 2.7	+ 2.3
1232	–8.9	–2.5	– 4.0	– 3.5
227–2	–7.4	–2.7	+ 2.3	–13.5
227–12	–3.8	+5.5	+ 3.3	– 1.0
Differences required for significance at odds 19:1	18.0	5.9	9.8	10.4

None of the differences in growth of the Baldwin tops in relation to stock was statistically significant. In the case of Yellow Transparent and Jonathan, the trees on clone 1225 were larger, with odds of 19:1 for significance, than those on clone 323 or on French Crab seedlings. In the the case of trees with Northern Spy tops, all variety-stock combinations made about the same growth, except that trees on clone 227–2 were smaller than those on all other stocks, with odds of 19:1 for significance in every case but one.

Discussion

The results have provided an opportunity to observe the performance of 12 scion varieties on eight or more different clonal stocks. The evidence indicates that among vegetatively vigorous apple seedlings from a single female parent (in this case Northern Spy), certain seedlings may, when budded to certain varieties, induce great retardation in growth of the tree. However, stocks that showed this retarded growth with some scion varieties developed satisfactory trees when budded with other varieties. The behavior of clone 227, causing the death of the young trees of many varieties, as well as weak growth of the top of other varieties, is an indication of the extent to which genetical makeup of the seedling apple stock can influence the scion-stock combination.

The evidence also suggests that certain commercial varieties used as scions are either unusually sensitive to or have an unusually great influence upon the factors in the stock that determine the development of the tree. Thus York Imperial on clones 1227, 1267, 1291, and 1303 was dwarfed, but Stayman Winesap was not. Similarly Wealthy and Rome Beauty were dwarfed on clones 1256, 1283, and 1300, but McIntosh was not. In fact, none of these clonal stocks has dwarfed all varieties. Since the scion-stock union was several inches above the soil, scion rooting was not involved. Furthermore, the death of Winesap-21 and of Delicious-2-157, on clone 227, while Winesap-19 and Delicious 27 grew satisfactorily, suggests that mutations (which in these cases were selected for fruit-color differences) may also influence the scion-stock congeniality. These results emphasize that the performance of several varieties on a clonal stock are not necessarily indicative of the behavior of other varieties on that stock.

The fact that McIntosh, Winesap, and Yellow Newtown grew satisfactorily in some cases but did not in other cases, could have been due to mutations of these three varieties, the mutants differing in their compatibility with clone 227. However, the occurrence of one or more viruses, symptomless in most scion and stock clones but causing death or retarded growth of certain clones, could also explain the observed results. For instance, there could conceivably be in certain trees of McIntosh a form of an apple virus that is lethal to clone 227, causes weak growth of rootstock 227–2, but is symptomless in other clones. However, evidence is still lacking to prove such a hypothesis.

Inasmuch as the trees in these experiments were planted too close to permit adequate light for fruiting, no conclusions can be drawn as to the possible value of these clones in producing a dwarfed but fruitful tree of a specific scion variety. Clones 1227, 1267, 1291, and 1303 would be worth testing experimentally to determine their effects upon dwarfing and early fruiting of all improved strains of York Imperial. Likewise, the dwarfing effect of clone 227–2 might well be determined for McIntosh with budwood from widely different sources.

The satisfactory growth of Starking, Stayman Winesap, York Imperial, Rome Beauty, McIntosh, Winesap, Williams, and Wealthy on clones 316 and 323 confirms the results obtained elsewhere (9, 11). However, clones 316 and 323 have not as yet proved to be so definitely superior to commercially available seedlings as to recommend their general use in commercial orchards. The results with clone 1225 indicate that this clone has possibilities of producing larger trees of some varieties than does either clone 316 or clone 323. Therefore clone 1225, budded to commercial varieties, deserves further experimental trial, especially where root injuries from woolly aphis or from cold are encountered.

SUMMARY

Apple seedlings that have unusual vigor, resistance to woolly aphis, and ready increase from root cuttings were propagated as clones, and their behavior as stocks for commercial varieties was observed. Clone 227 was incompatible with many varieties, death of the trees occurring in the first, second, or third year. Eleven clones, namely, 227–2, 1227, 1232, 1256, 1267, 1270, 1283, 1288, 1291, 1300, and 1303, each caused some degree of dwarfing with specific scion varieties, but not with all. In contrast, nine clones, namely, 323, 329, 1223, 1225, 1226, 1241, 1251, 1263, and 1297, when budded to York Imperial, produced larger trees than did French Crab seedlings. Clone 1225 produced larger York Imperial and Jonathan trees than did clones 316, 323, and 329; and larger Yellow Transparent trees than did clones 316 and 323, by odds of 19 : 1.

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Growth Behavior of Four Apple Varieties on Manchurian Crab Seedling Rootstocks in the Nursery[1]

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AMONG the new apple rootstocks the Manchurian Crab *Pyrus baccata* var. *Mandshurica,* (Maxim.) is of great interest. Manchurian Crab seedling rootstocks now in use are second generation seedlings of seed gathered in 1924 by Professor N. E. Hanson of the South Dakota Experiment Station while on an expedition in the mountain regions 50 miles east of Harbin, Manchuria (1). Although these seedling rootstocks have been used in Minnesota and South Dakota where hardiness of the root system of apple trees is an important factor, no information on the behavior of commercial varieties on Manchurian Crab roots has appeared in the horticultural literature. It is the purpose of this paper to report on the growth performance in the nursery of four apple varieties when budded on such seedlings.

MATERIALS AND METHODS

Two hundred twenty 1-year-old Manchurian Crab seedlings obtained from the South Dakota Experiment Station were lined out on May 6, 1943 in the nursery at the New York State Agricultural Experiment Station, Geneva, New York. The soil at the nursery location is a stony Ontario Loam of high fertility level. The seedlings were of slightly smaller and less uniform size, 4 to 5 mm in diameter, than desired for apple lining-outstock in New York State. On August 9, 1943, seedlings of sufficient size were budded with the apple varieties Cortland, Delicious, McIntosh and Virginia Crab. Observations on the growth of the seedlings and buds were made and trunk diameter increase and shoot growth of the budded varieties were measured and recorded in the fall of 1944 and 1945.

OBSERVATIONS

Growth of the Lining-out Stock:—Although the size of the individual seedlings was smaller and variation in regard to diameter and length was greater than normally accounted in seedling lining-out stock used in fruit tree nurseries, growth of the seedlings after lining to the nursery was surprisingly good. All seedlings took hold rapidly and started new shoot growth within 3 weeks from planting. The foliage throughout the growing season remained healthy. Stunting of the young shoot growth caused by the nymph of the apple leaf hopper *Empoasca mali,* (Harr.), which is very serious with so-called domestic apple seedling rootstocks, was not observed.

At the beginning of August, 1943, out of 220 seedlings planted, 182 or 82.7 per cent had made sufficient growth to be budded. Fifty seedlings were budded to the variety Cortland, 53 to Delicious, 40 to a solid red strain of McIntosh, and 39 to Virginia Crab. The bark

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separated well and buds of the above varieties were easily inserted. Union between variety and rootstock seemed to take place within from 14 to 20 days. All inserted buds remained dormant until spring 1944.

Growth From the Bud to the 1-Year Whip:—The buds of all four varieties started to develop shoot growth in early May and up to May 29 new growth up to 10 inches tall had been produced. This new growth was exceedingly vigorous with Virginia Crab and vigorous and very uniform with Cortland and Delicious. The leaves were large and of dark green color and growth was stocky. It appeared at this time as if the Manchurian Crab seedlings would be very desirable rootstocks. Stands of buds obtained, with the exception of McIntosh, were very satisfactory. As seen from Table I, the stand of budded trees on May 29, 1944, was: Cortland, 88 per cent; Delicious, 86.8 per cent; and Virginia Crab, 84.6 per cent.

TABLE I—STAND OF BUDS AND NUMBER OF 2-YEAR TREES OBTAINED

Variety	Number Budded	Number Buds Growing	Per Cent Stand of Buds, Spring 1944 (Per Cent)	Number 2-Year Trees	Per Cent Stand 2-Year Trees (Per Cent)
Cortland	50	44	88.0	38	76.0
Delicious	53	46	86.8	46	86.8
McIntosh	40	20	50.0	15	37.5
Virginia Crab	39	33	84.6	16	41.0

The McIntosh buds were variable in regard to length growth. During the sprouting operation in early May (the removal of young shoots other than the inserted bud) it was found that the McIntosh variety had made a poor union. At this time buds separated easily from the stock by applying slight pressure with the thumb. When final bud counts were taken only 20 out of 40 budded, or a stand of 50 per cent, remained at the end of May.

A thunder storm at the nursery location on June 5, followed by strong winds on June 16 and July 11, acted as a severe test of the union between the budded variety and the rootstock. As seen from Table II, 6 out of 44 buds were broken out by wind with Cortland, 5 out of 20 with McIntosh, and 17 out of 33 with Virginia Crab. It must be pointed out that the apparent lower loss with McIntosh is due to the fact that the weakest unions already had been eliminated by breakage during sprouting.

Virginia Crab had very large foliage and had up to June 5 made the strongest growth and thus no doubt was more severely affected by the wind, but it was also apparent that the union between the Virginia

TABLE II—NUMBER OF BUDS BROKEN OUT BY WIND DURING FIRST GROWING SEASON AFTER BUDDING

Variety	Number Buds Growing	Broken by Wind			Number Buds Remaining	Percentage Broken Out
		June 5	June 16	July 11		
Cortland	44	0	3	3	38	13.6
Delicious	46	0	0	0	46	0.0
McIntosh	20	0	5	0	15	25.0
Virginia Crab	33	10	7	0	16	51.6

Crab bud and the Manchurian Crab stock was not very secure. In contrast, throughout this period not one single bud of Delicious was lost by wind breakage, proving quite clearly the strong union between the Delicious variety and the Manchurian Crab rootstock.

The remaining buds of all four varieties grew satisfactorily and by fall produced strong 1-year whips. The mean trunk diameter at the end of the 1944 growing season was nearly identical with Virginia Crab and Delicious, whereas for Cortland and McIntosh was somewhat smaller, but still within the limits of the size of a number one grade nursery tree (Table II). Uniformity within the trees of each variety was greatest with Cortland and Delicious.

Greatest length growth at the end of the 1944 growing season was produced by Delicious, with a mean height of 51.8 inches, followed by Cortland with 48.5 inches, Virginia Crab 43.3 inches, and McIntosh 41.7 inches (Tables III). Not only did Delicious produce the greatest height, but also reached within its 46 trees the greatest uniformity, Cortland followed very closely. Greater variation existed in Virginia Crab and McIntosh.

TABLE III—MEAN TRUNK DIAMETER AND MEAN SHOOTGROWTH OF 1-YEAR AND 2-YEAR OLD APPLE TREES ON MANCHURIAN CRAB SEEDLING ROOTSTOCKS

Variety	Number Trees	Mean Trunk Diameter (Mm)		Mean Total Shootgrowth (Inches)	
		1-Year Olds	2-Year Olds	1-Year Olds	2-Year Olds
Cortland	38	13.7 ±0.245*	18.7 ±0.497	48.5 ±1.242	250.0 ±15.441
Delicious	46	15.3 ±0.295	19.8 ±0.369	51.8 ±1.159	271.2 ±10.594
McIntosh	15	12.6 ±0.616	16.5 ±0.261	41.7 ±3.009	141.5 ±21.279
Virginia Crab	16	15.4 ±0.526	22.3 ±0.799	43.3 ±2.289	234.5 ±20.049

*Standard Error of the Mean.

Growth of 2-Year Old Trees:—On March 6, 1945, all 1-year whips were headed back to a height of 32 inches. At this date an interesting observation was made. The 16 Virginia Crab trees had all developed flower buds, many of which were located at the terminal end of the whips. Two McIntosh trees showed the same condition, but no flower buds appeared on either Delicious or Cortland. Such flower bud formation on 1-year old trees must be considered on indication of an abnormal union between stock and scion.

During the second growing season Virginia Crab held its position of greatest trunk diameter increase, with a gain of 6.9 mm but remained in third place in regard to total shoot growth. Cortland gained 5 mm in trunk diameter and Delicious 4.5 mm. Although Cortland gained more in trunk diameter it did not overtake Delicious in total shoot growth. Thus Delicious kept first place in total shoot growth as seen from Table III, with a mean growth of 271.2 inches followed by Cortland with a mean growth of 250 inches. The outstanding factor for Delicious was the uniformity of growth obtained. Total mean shoot growth for Virginia Crab was 234.5 inches and for McIntosh 141.5 inches. The variation in shoot growth within each variety was greatest with McIntosh, followed closely by Virginia Crab. On the other hand, Cortland with the exception of four trees in a total of 38 produced very uniform growth.

Root System and Union:—The root system of the Manchurian Crab rootstock was very fibrous (Fig. 1), strong lateral roots, typical for 2-year-old apple trees when grown on domestic apple seedlings, were absent. The largest roots on the trees discussed were not over 7 mm in diameter. Such roots also appeared somewhat brittle and were easily broken.

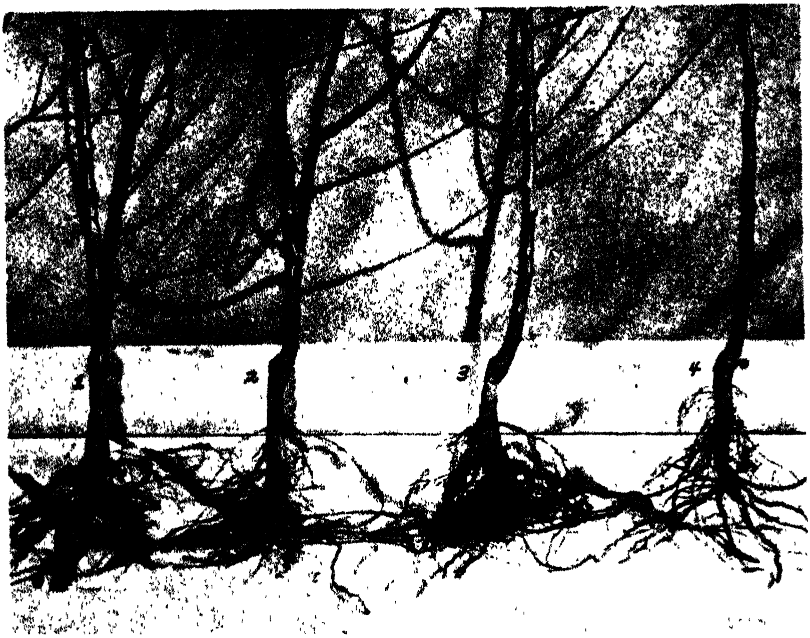

FIG. 1. Representative 2-year-old nursery trees on Manchurian Crab showing the root system of the rootstock and the bud union produced. 1. Cortland; 2. Delicious; 3. Virginia Crab; 4. McIntosh.

The union between stock and scion appeared normal with Cortland and Delicious, that is, the stock and the scion grew at the same rate, thus producing a smooth and even union. McIntosh showed a slight swelling at the point of union indicating that the growth rate between the stock and the scion was not uniform. A swelling at the bud union was pronounced with Virginia Crab and this variety appeared to grow at a faster rate than the Manchurian Crab seedling.

DISCUSSION

The stock and the scion growing uniformly at the bud union will produce long-lived vigorous and productive trees. Such bud unions indicate good fusion of tissues and ready passage of nutrients. Whenever the growth rate of the rootstock is slower than the scion, swelling and overgrowth of the scion at the point of union will result. If such swelling becomes extreme the resulting tree will be dwarfed and may be short-lived (2). The varieties Cortland and Delicious when budded to Manchurian Crab seedlings have produced in the nursery satisfactory smooth bud unions, and vigorous shoot growth. There is indication that the union between Delicious and the Manchurian Crab is very strong and that the Manchurian Crab may be well suited as a rootstock for Delicious. Cortland also may successfully be propagated on this stock. Under conditions of high winds at the time the young bud starts to grow in the spring, as occurred at Geneva, some buds may break off and this may influence the total stand of buds obtained.

Virginia Crab and the red strain of McIntosh tried at the Geneva Experiment Station appear to be not completely congenial with the Manchurian Crab stock. The total stand of buds with Virginia Crab and McIntosh may even under favorable growing conditions be expected to be much lower than that of varieties such as Cortland and Delicious.

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Malling Stocks at the Ohio Agricultural Experiment Station

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Standard commercial apple varieties budded on Malling stocks have been tested at Wooster during the past 6 years. The stocks utilized are Malling I, II, IV, V, VI, VII, and XIII. The varieties selected with year of planting follows:

Stayman Winesap	Spring 1940 and 1941
Jonathan	Spring 1940 and 1941
McIntosh	Spring 1942
Delicious	Spring 1943 and 1944
Cortland	Spring 1944
Franklin	Spring 1944
Northern Spy	Spring 1944

The trees are grown in grass mulch and fertilized annually with a nitrogen-carrying fertilizer. They have been examined within the past year for scion-rooting, which was nowhere in evidence.

Growth, as indicated by circumference of the trunk, was measured annually and the weight of prunings recorded. The trees on the dwarfing stocks planted in the spring of 1940 produced first bloom in 1943. A full crop of fruit, which would have been obtained on nearly all of the trees planted in 1940 and 1941 (with the exception of the domestic seedlings), was prevented by the 1945 frost. The data are presented in Tables I and II for the earliest plantings.

Stayman Winesap:—The data in Table I show, in descending scale, the relative trunk circumference of the trees on the various stocks. Malling IV is superior in the 1940 planting while Malling VI heads the list of trees planted in 1941. The rank of Malling I for 1940 is nearly reversed in the 1941 planting. Malling VII made excellent growth compared to Malling II and V.

When the growth made by each of the stocks is compared, year by year, during the 5-year period some revealing trends are evident. Malling IV has consistently produced more favorable results over the period. Malling I has more or less maintained its rank, while Malling II has consistently shown a downward trend, which is also the case for Malling VII. Results with Malling V and VI were more or less variable, with downward trends indicated. As would be expected trees on domestic seedling stocks have approached top rank although trees on Malling IV still exceed them in circumference, a situation not likely to continue. On the basis of the present trend we may expect the size of the trees grown on these different stocks to rank as follows: (1) domestic seedlings; (2) Malling IV; (3) Malling I.

On the basis of earliness of bearing, Malling IV, Malling I, and Malling VII were superior.

The trees were pruned very little; as yet there is no consistent evidence in this respect. As might be expected, the greatest weight of prunings was obtained from the seedling stock.

TABLE I—TRUNK CIRCUMFERENCE AND YIELD OF VARIOUS VARIETIES ON MALLING AND SEEDLING STOCKS. JANUARY 1, 1946

Stock	Average Circumference per Tree (Inches)	Average Yield per Tree (Pounds)	
	Stayman Winesap, Trees Planted Spring 1940	*1943*	*1944*
Malling IV	12.67	0.30	7.60
Domestic seedlings	10.53		0.22
Malling I	9.79		7.00
Malling VII	9.50	0.14	5.56
Malling V	9.33		2.17
Malling II	8.83	0.27	4.50
Malling VI	8.81	0.05	0.75
	Stayman Winesap, Trees Planted Spring 1941		
Malling VI	7.08		0.23
Malling VII	7.00		0.62
Malling IV	6.96		1.63
Malling XIII	6.92		0.00
Malling II	6.84	0.10	
Malling V	6.52		0.07
Malling I	6.08		0.67
	Jonathan, Trees Planted Spring 1940		
Malling I	8.64	0.03	2.63
Domestic seedlings	8.50		0.35
Malling IV	8.31	0.53	1.10
Malling II	8.28	0.15	1.62
Malling V	7.82		0.52
Malling VI	7.52		0.25
Malling VII	6.88	0.08	3.30
	Jonathan, Trees Planted Spring 1941		
Malling V	7.01		0.15
Malling XIII	6.76		0.00
Malling II	6.45		0.15
Malling IV	5.95		0.10
Malling VII	5.81		0.06
Malling I	5.64		0.10
Malling VI	3.53		0.00
	McIntosh, Trees Planted Spring 1942		
Malling XIII	6.58		0.00
Malling IV	6.37		0.00
Malling VII	6.33		0.00
Malling V	6.02		0.00
Malling II	5.86		0.45
	Delicious, Trees Planted Spring 1943		
Malling XV	3.52		
Malling XII	2.70		
Malling XIII	2.52		
Malling III	2.06		
Malling X	2.04		
Malling VII	1.83		

Jonathan:—Casual examination of the relative growth of Jonathan on the various Malling stocks shows no outstanding trends. Malling I, which was superior in the 1940 planting, was almost at the bottom of the list in the 1941 planting. Trees on Malling II and IV have made greater growth than those on Malling VII and VI.

But comparison of the data for each of the various years shows certain trends. The domestic seedling stock will shortly excel in growth while Malling II and IV are merely holding their own. On the other hand, trees on Malling VI and VII are falling behind to a marked degree. Malling XIII shows an accelerated growth.

On the basis of earliness of bearing, Malling IV, I, and VII are superior.

TABLE II—WEIGHT OF PRUNINGS REMOVED FROM TREES OF VARIOUS VARIETIES ON MALLING AND SEEDLING STOCKS. 1945

Stock	Average Weight of Prunings per Tree (Pounds)
Stayman Winesap, Trees Planted Spring, 1940	
Malling II	1.73
Malling VI	1.91
Malling VII	1.97
Malling IV	2.11
Malling I	2.18
Malling V	2.30
Domestic seedlings	3.66
Stayman Winesap, Trees Planted Spring, 1941	
Malling I	0.42
Malling V	0.61
Malling VI	0.84
Malling XIII	1.02
Malling II	1.17
Malling IV	1.20
Malling VII	1.26
Jonathan, Trees Planted Spring, 1940	
Malling V	2.37
Malling VII	2.64
Malling VI	2.76
Domestic seedlings	2.77
Malling II	3.07
Malling IV	3.19
Malling I	3.37
Jonathan, Trees Planted Spring 1941	
Malling VI	0.15
Malling VII	0.80
Malling I	1.00
Malling II	1.12
Malling IV	1.22
Malling V	1.42
Malling XIII	1.79
McIntosh, Trees Planted Spring 1942	
Malling II	0.63
Malling VII	0.70
Malling XIII	0.87
Malling V	0.92
Malling IV	1.16

McIntosh:—The growth of McIntosh trees on Malling XIII exceeds those on Malling I and VII only slightly. Trees on Malling II are the smallest to date

Delicious:—Trees on vigorously-growing Malling XV and XII exceed those on Malling X and VII, as would be expected.

General Considerations:—The trees are growing in a soil which permits deep rooting, as indicated by the fact that mature trees in adjacent orchards possess roots extending 10 feet in depth. Despite this fact trees on Malling stocks have shown considerable leaning and, in some instances, have required support. In the earlier years considerable heaving was also evident. Many of the trees were easily shaken by hand indicating poor rooting. This situation, however, now shows some improvement. Compared with trees on seedlings stocks, the trees on several of the Malling stocks have made excellent top growth.

GENERAL CONCLUSIONS

In general, with the varieties here noted, Malling IV appeared superior to the other dwarfing stocks. Trees on Malling VII have done well by comparison but, from present indications, it will, as expected, form smaller trees with Stayman Winesap, Jonathan, McIntosh, and Delicious than Malling IV. Malling I has grown well and produced early with Stayman Winesap but it may not be quite as satisfactory with Jonathan.

Under the soil and climatic conditions at Wooster trees on the Malling stocks have shown considerable heaving and leaning although the situation is improving.

Can Apple Trees on Clonal Rootstocks be Recommended for Commercial Orchards in the Shenandoah Valley?[1]

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GENERAL CONSIDERATIONS

At Kearneysville, West Virginia, Block O which consists of apple trees on selected rootstocks was set in December, 1941. The scion varieties are Delicious, Stayman Winesap and York Imperial. These were budded by the cooperating agency, the Bureau of Plant Industry, United States Department of Agriculture, on eight rootstocks of which seven are clones and one is a lot of French Crab seedlings.

The clonal rootstocks are United States Department of Agriculture selections, numbers 312, 316, 323, 329, 1225, 1256, and 1263. Of this series, 316, 323 and 329 are the most widely known; they appear in the immediately adjacent Block A, where they have been under observation for 13 seasons. In this older orchard, trees on 316 and 329 were used in alternate third rows as standards of comparison for the performance of the trees on all of the other rootstocks (3).

USDA 312 was propagated from a selected Vermont Crab seedling similar to that from which clones 316, 323 and 329 were obtained.

USDA 1225 is the most promising rootstock developed from a group of Briar Sweet x Mercer seedlings received by G. E. Yerkes, Bureau of Plant Industry, from the late T. J. Maney, Iowa State College, in 1930. Clone 1225 has a high degree of cold hardiness — a factor not of great importance at Kearneysville — and is said to induce more vigorous scion growth with York Imperial or Jonathan than does 316, 323 or 329.

USDA 1256 and 1263 are two of a large number of selected seedlings grown from open-pollinated seed of Northern Spy. Unlike most Northern Spy seedlings, the parents of these two clones do not show hairy-root. Clone 1256 is rated as a rootstock inducing some degree of dwarfing in the case of specific scion varieties.

Seedling Rootstocks in Block O:—The French Crab seedlings were purchased from nurseries at Shenandoah, Iowa, where they were grown in 1939. They were set in the nursery row at Beltsville, Maryland, in the spring of 1940 as 1-year straight-root seedlings. The propagators are reasonably certain that the seedlings were actually French Crab, not seedlings of domestic varieties.

Planting Plan of Block O:—Block O contains 10 plots lying side by side in one tier. All plots have three rows of 16 trees. Each row contains a single scion variety, Delicious, Stayman Winesap or York Imperial. All eight rootstocks appear in every row and are arranged as adjacent pairs of trees on the same rootstock. The planting distance is uniformly 20 x 20 feet.

The sequence of the varieties within the plots is fortuitous and in five instances two rows of the same variety in adjoining plots occur together. The distribution of the rootstocks in the rows is at random subject to the restriction that no pair lies opposite trees on the same selection in the rows on either side, whether within the same plot or in an adjacent plot.

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[1] Published with the approval of the Director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 353.

There are 20 trees of each combination of variety and rootstock exclusive of the guard rows on three and part of the fourth sides of the orchard. These are composed of extra trees of some of the combinations appearing in the plots. This report is not concerned with the guard trees, which showed the same general condition as did the plots.

The Weather in September, 1945:—The precipitation for September, 1945, according to the official Weather Bureau station at Kearneysville was 7.94 inches for the wettest September of record as compared with the average of 3.33 inches. Two days of rain — 1.75 inches on the 17th and 3.15 inches on the 18th — thoroughly softened the soil.

Although no actual velocities were measured, wind was not a problem in September, 1945. The trees were subjected to at least no more than the usual amount of wind stress.

Damage and Its Classification

After this period, it was observed that a considerable proportion of the trees were leaning, Fig. 1, and would have to be straightened, then guyed or braced, due to the failure of the roots to support the tops properly. On October 16, the trees were classified as to their tendency to lean. The criterion was somewhat arbitrary. Those which possessed an angle with the vertical of more than approximately 10 degrees were classified as leaning; most of the "leaners" exceeded this figure. It is possible that many of the trees not considered as leaning at that time will eventually reach that condition.

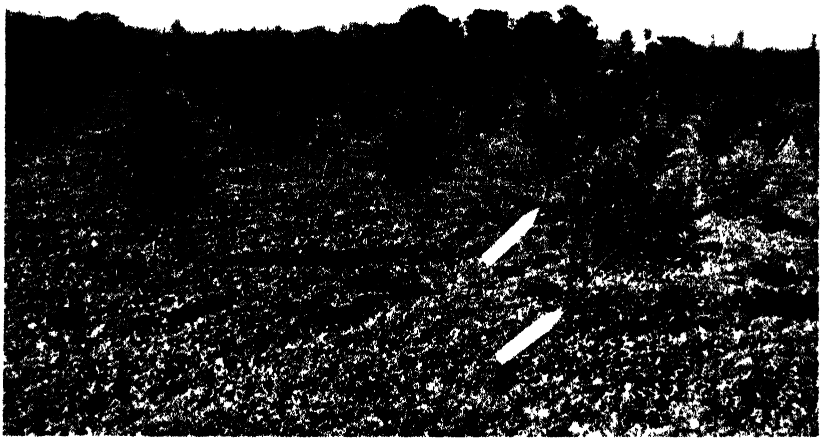

Fig. 1. Two leaning trees, York Imperial on Clonal rootstocks. Block O, Kearneysville, W. Va., October 16, 1945, after a wet September.

The check was made without reference to the rootstock key. Table I shows the results of the survey.

DISCUSSION

From Table I, it is evident that only one tree of a combination including a seedling rootstock, York Imperial/French Crab, was included in the leaners. The table does not show the regrettable fact that it was the large, vigorous trees that tended particularly to lean.

TABLE I—NUMBERS OF TREES LEANING AFTER A WET SEPTEMBER BLOCK O, KEARNEYSVILLE, W. VA., OCTOBER, 1945*

Variety	Rootstocks								Totals
	312	316	323	329	1225	1256	1263	French Crab	
Delicious	1	1	2	2	2	1	3	0	12
Stayman Winesap	4	3	2	3	5	2	1	0	20
York Imperial	4	1	3	4	2	3	1	1	19
Totals	9	5	7	9	9	6	5	1	51

*20 trees of each combination set in December, 1941.

Sudds and Marth (2) reported a somewhat similar situation resulting from a severe local windstorm on July 28, 1940. Then Gallia Beauty, Starking, Staymared, and York Imperial trees in adjacent Block A showed on the average twice as much wind damage when worked on clones as when the rootstocks were seedlings. In contrast, however, the soil was firm in 1940 and thus it afforded a maximum degree of root anchorage; in addition to leaning and upset trees, both usually involving root fractures, much breakage of the tops was involved, except with Gallia Beauty. With both extremes of soil moisture, clonal rootstocks as a class have failed to support the tops as adequately as have the seedlings.

Inadequate Rooting Not Confined to Clones:—The inference should not be drawn that inadequate rooting in similar plantings for rootstock research may be expected to be confined almost exclusively to trees on clonal rootstocks. For example, in the previous report on wind damage (2), Grimes Golden seedlings worked to Starking, Gallia Beauty and York Imperial showed the same type of weakness. It is clear, however, that at Kearneysville, apple trees on clonal rootstocks as a group have been peculiarly subject thus far to one variant or another of wind injury.

Wind Resistance Desirable in the Shenandoah Valley:—A considerable degree of wind resistance is a highly desirable quality in apple rootstocks for use in the Shenandoah Valley. Although some clonal selections possess outstanding yield records, the general susceptibility to wind injury of apple trees on such rootstocks at Kearneysville throw considerable doubt on the wisdom of recommending, at least in the near future, their use in commercial orchards under similar conditions. While certain clones may yet prove themselves to possess sufficient wind resistance, there will remain the question of varietal adaptation. One specific rootstock may not do so well for these three varieties. Thus for the half-dozen leading varieties of the area, the rootstock problem may become more complicated.

Lack of Other Seedling Rootstocks Regrettable:—It is indeed unfortunate that several of the more promising seedling rootstocks grown from domestic varieties were not included in Block O. No attempt should be made to read into Table I an approval, expressed or implied, of the use of French Crab seedlings as rootstocks, since only the one factor of adequate rooting is concerned in this report. The views of the writer concerning the performance of French Crab seedlings at Kearneysville have been stated previously (1).

SUMMARY

At Kearneysville, West Virginia, apple trees on clonal rootstocks again have shown to a disquieting degree the tendency to be subject to wind injury. Their general susceptibility to such damage makes recommendations approving their use in commercial orchards in the Shenandoah Valley doubtful at any time in the near future.

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The Presence of Mydriatic Alkaloids in Tomato Fruit from Scions Grown on *Datura Stramonium* Rootstock

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In certain sections of the southern part of the United States it is difficult to grow tomatoes because the plants are seriously damaged by certain root-knot forming nematodes. It has been found that by gafting scions of the tomato on *Datura stramonium* (jimson weed, stramonium) rootstock which is not subject to damage by the nematodes, the fruit can be produced very successfully. Isbell (6) has described in detail how the grafting may be accomplished for home gardens. It apparently has been a practice for many years in various sections of the South. Since stramonium normally contains poisonous alkaloids the question arose as to whether some of the alkaloids may not be translocated from the rootstock through the plant sap to the tomato fruit. Persons in the South who are familiar with this practice have informed the writers that they do not recall any cases of poisoning having been reported as a result of eating the fruit from plants grown in that way. However, the effects of minute quantities of alkaloids of this type might easily go unnoticed by the layman. The physical symptoms resulting from the ingestion of small quantities of the alkaloids of *D. stramonium* are described in the United States Dispensary, 23rd edition, as follows:

> "A dose of more than 1.3 milligrams (one-fiftieth of a grain) of atropine should never be taken at one time although in certain intestinal disturbances as much as 3 milligrams (one-twentieth of a grain) have been administered. In susceptible persons 0.6 milligram may cause decided dryness of the throat and a dose of 1.3 milligrams may result in additional symptoms such as dilated pupils of the eyes, rapid pulse and increased respirations. The symptoms may persist for several hours but finally disappear with no further disturbances. After large doses alarming symptoms such as depression with stupor, weakening of the pulse and respiratory failure may develop which usually end in recovery."

In view of the facts stated, it is entirely possible that persons may eat moderate quantities of the fruit from tomato scions grown on the jimson weed, containing small amounts of the alkaloids without noticing such effects or without being aware of the cause of such effects if they are observed. The present investigation was undertaken to determine whether alkaloids are likely to be present in sufficient quantity in the fruit thus grown to cause definite symptoms and whether the consumption of such fruit in normal quantities presents a serious health hazard.

Review of Literature

Other investigators have shown that alkaloids are translocated from rootstock to scion in the case of grafts of tomato on certain other alkaloid-containing Solanaceae. It has been definitely established by chemical means, that the stems and leaves of tomato scions contain alkaloids of the same nature as those contained in the rootstock on which they were grown. Much smaller amounts, although shown to be present in the fruit by biological tests, have not been quantitatively determined with any degree of accuracy by chemical analysis. Javillier (*7*) in 1910, on studying the migration of alkaloids in grafts of the Solanaceae, found by both chemical and physiological tests that tomato fruit from scions grafted on belladonna rootstock contained mydriatic alkaloids while the stems and leaves gave negative results. Very doubtful chemical and physiological tests for alkaloids were obtained on extracts of fruit from tomato plants on which belladonna grafts were grown. Further tests were thought to be necessary in view of these results. Daniel and Ripert (*2*) in 1923, while investigating the effect of grafting on the chemical composition of plants found that tomato scions grafted on belladonna rootstock showed traces of alkaloids and that the graft scar tissue and swollen parts at the juncture were rich in alkaloids. Kraevoi and Nechaev (*9*) in 1941 reported that biological tests made with the aid of the electrocardiograph on extracts of the fruit from scions of *Solanum lycopersicum* var. Tookwood, grown on jimson weed, *Datura stramonium*, showed considerable quantities of atropine to be present. The tomato leaves were removed from the grafts as fast as they formed. The taste of the fruit was inferior but edible. While investigating the morphogenetic interaction between stock and scion, involving 24 grafts of *Lycopersicon esculentum* and *D. stramonium*, Kerkis and Pigulevskaya (*8*), in 1941, found that atropine was present in all grafts of tomato on stramonium rootstock. The concentration varied greatly both in the different parts of the scion and in different scions, but it always was lowest in the fruit. The content of atropine in the leaves varied from 0.13 per cent to 0.25 per cent; in the stems, from traces to more than that contained in the leaves, while concentrations in the fruit could be detected only biologically. In the chemical analysis the procedure adopted could not detect atropine quantitatively, unless the concentration in the extract was higher than 1 : 16000. For the detection of smaller quantities the reaction on the pupil of the cat's eye was used. This test, it is pointed out, is extremely sensitive. Hieke (*4*), in 1942, reporting on an investigation of the formation of alkaloids in plant parts in widely diverse grafts of the Solanaceae found that tomato grafts on tobacco contained 900 to 1000 parts per million of nicotine in the fresh leaves but tobacco grown on tomato rootstock contained no nicotine, also tomato grafts on belladonna roots definitely contained atropine while belladonna herb grown on tomato roots gave negative results. The presence of alkaloids in grafted plant parts was found to depend on the same alkaloids being present in the rootstock. Studies by Cromwell (*1*), in 1943, on the synthesis of hyoscyamine in *Atropa belladonna* and *D. stramonium* show that alkaloids pass from the roots of belladonna to tomato scions grafted thereon but no alkaloids, or only very small amounts, appear in tomato stock with belladonna grafts. He concluded that the root evidently is the locus of synthesis of alkaloids which are carried to the aerial parts by the plant sap.

An investigation of the accumulation of alkaloids in reciprocal grafts of *Datura stramonium* with tobacco and with tomato by Peacock, Leyerle and Dawson (11) in 1944 showed that extracts of stramonium scions grown on tomato stock did not as a rule possess mydriatic activity, but approximately 0.12 per cent total alkaloids from which hyoscyamine was isolated, was extracted from a large lot of dry tomato herb grown on stramonium rootstock. In the same year Pal and Nath (10) demonstrated that in reciprocal grafts between *Nicotiana rustica* and *Lycopersicon esculentum* var. Pritchard nicotine is found in the tomato scion but when the tomato is the stock the nicotine in the tobacco scion is much reduced. Also in that year Tushniakova (12) found that when black nightshade, potato, or tomato are grafted on a species that contains nicotine or atropine then alkaloids are developed in the scions. In the reverse grafts, plants used as scions such as tobacco, bellodonna, *Hyoscyamus* and *Datura* contained no alkaloids or only very small quantities. Dawson (3) while determining the origin of nornicotine in 1945 found that nicotine was present in tomato scions grown on tobacco rootstock but none of the three major tobacco alkaloids occurred in tomato rootstock or in tobacco scions grafted thereon. Hills (5) at about the same time reported that the stem and leaves of tomato grafted on *Duboisia myoporoides*, a hyoscine containing plant, contained over one per cent of total alkaloids which included some hyoscine that was identified by the picrate test. It is pointed out that this is the highest concentration of alkaloids reported in tomato leaves but that this is not surprising since the alkaloid concentration in *Duboisia* leaf is several times greater than that usually found in *Datura* and *Atropa*.

Experimental Methods

In 1944 the Department of Horticulture and Forestry, Alabama Polytechnic Institute, Auburn, Alabama sent fruit and herb from tomatoes grown there in the normal way and fruit from tomato scions grafted on stramonium rootstock to the Division of Tobacco, Medicinal and Special Crops for examination. The herb and fruit was dehydrated and assayed. The herb of the grafted plants contained appreciable quantities of stramonium alkaloids and the fruit smaller amounts. When assayed by the same method alkaloids were not found in corresponding parts of the normally grown plants.

In order to investigate this problem more thoroughly and determine the quantity of alkaloids present in tomato fruit grown on stramonium rootstock three varieties of tomatoes were grown in the usual way and as scions on two varieties of stramonium at Beltsville, Maryland in 1945. The concentration of alkaloids present in the herb and fruit was determined by chemical means and the physiological effects of the fruit were determined by biological tests. The tomato varieties chosen, Marglobe, Columbia and Golden Jubilee, represent fruit of varying acidity. These were grafted on the wild, purple-stem, and the cultivated green-stem varieties of *Datura stramonium*.

Grafting:—Plants of the several varieties of tomatoes and stramonium, grown from seed planted in the greenhouse late in February, were grafted on the stramonium by the interarch method when 5 to 6 inches high. Single plants of the two to be grafted were planted side by side in a 4-inch clay pot and joined together about 3 inches above the soil surface. About 10 days to 2 weeks later the stramonium tops were cut off immediately above the graft union and the tomato stems severed immediately below it. After shading for a few days to prevent wilting the plants were kept in a cool house until May 8 when they were transplanted to the field. They were 12 to 16 inches in height at the time of transplanting. Twenty-five plants of each variety of tomato grafted on each of the stramonium varieties in addition to 25 control plants of each were spaced 4 x 4 feet in the field. The grafted plants were staked and kept pruned and tied to the stakes so that no part of the tomato scion could make contact with the soil by means of adventitious roots. Thus all nourishment received by the tomato scions was obtained from the stramonium rootstock by way of the plant sap. The plants made excellent growth and began to mature fruit early in July.

Preparation of Samples for Assay:—Alkaloid determinations were made on both the green and vine-ripened fruit. The preparation of the fruit for chemical assay so that there would be no loss of alkaloids required much preliminary work before a practical procedure could be devised. The fruit dried alone at a low temperature could not be easily ground to a fine powder for extraction. Several methods of dehydrating were tried and the effect on the alkaloid content determined by assay. Because of the hygroscopic and gummy nature of the dehydrated pulp it was necessary to add some inert substance before drying to facilitate the grinding of the dried material to a fine powder. The addition of plaster of Paris or gypsum in the proportion of 1 to 10 of the fresh fruit previously pulped in a Waring blender resulted in a product that could easily be ground to a fine powder after drying in an electric, forced-air oven at 55 to 60 degrees C for 18 to 24 hours. When a definite quantity of fresh stramonium leaf was added to the above mixture before drying and the powdered material then assayed in comparison with a similar quantity of the leaf slowly air dried as a control, the results indicated that the stramonium alkaloids are not destroyed by the procedure described. The use of hydrated lime instead of the other materials mentioned resulted in the loss of the alkaloids. Extraction of the alkaloids from the fresh or partly dehydrated fruit with ether or chloroform or an ether-chloroform mixture (3 parts of ether and 1 of chloroform by volume) resulted in troublesome emulsions which required considerable time to separate. Fruit completely dried with plaster of Paris or gypsum gave much less trouble in this respect. At each harvest date, 300-gram samples of mature fruit picked from the control plants of each of the three varieties and dried in the same manner as fruit from the grafted plants gave negative results on assay.

Chemical Assay:—The total alkaloids in the tomato fruit, leaves, stems and roots were determined essentially by the procedure for alkaloidal assay as described in the United States Pharmacopœia, Edition XII, with certain modifications made necessary by the volume or physical state of the material to be assayed. Briefly, the determinations consisted in first extracting the alkaloids from the material as prepared with an ether-chloroform mixture made strongly alkaline with ammonia. The exact procedure to be followed was determined by the size of the sample or whether it was used in the fresh or dried state. The extraction of total alkaloids from the material was accomplished by shaking definite quantities of a mixture of solvent and sample in alkaline solution for about 2 hours followed by maceration overnight. After filtering either an aliquot portion of the filtrate containing the alkaloids or the total volume combined with successive washings with fresh solvent was evaporated to near dryness and redissolved in 100 milliliters of ether. The ether solution was then extracted by shaking with successive portions of 2½ per cent sulfuric acid. The combined acid extracts were made alkaline with ammonia and the alkaloids removed by shaking with successive portions of chloroform. The chloroform extracts were combined, evaporated to dryness on a steam bath, redissolved in a small portion of chloroform and again evaporated to dryness and this step repeated a third time to insure the complete removal of any volatile bases present. The final residue was taken up with an excess of 0.02 normal sulfuric acid solution and the excess determined by titrating with 0.02 normal alkali solution. The number of milligrams of total alkaloids present was obtained by multiplying the number of cubic centimeters of the acid neutralized by the alkaloids with the factor 5.787. Repeated tests with Mayer's reagent and the nitric acid-alcoholic potassium hydroxide color test for atropine as described in the United States Pharmacopœia, Edition XII, confirmed the presence of the alkaloids as indicated by the titrimetric tests.

Bioassay:—The concentration of the mydriatic alkaloids in the tomato fruit and foliage can be roughly approximated by applying extracts of such to the eyes of dogs and noting the degree of mydriasis in comparison with a solution of atropine sulfate of known strength. A number of extracts of such parts of tomato plants grafted on stramonium rootstock and of others grown normally were tested in that way by the Division of Pharmacology, Food and Drug Administration, Federal Security Administration as a check on the results obtained by chemical assay.

EXPERIMENTAL RESULTS AND DISCUSSION

Preliminary tests were begun on the first fruit maturing early in July, and by July 20 sufficient mature fruit was available for a series of assays. Alkaloid determinations were made on the green and vine-ripened fruit from both grafted and control plants. The foliage of both was also assayed at intervals during the season to determine its alkaloid content. These results are recorded in Tables I and II.

The data in Table I show some variation in alkaloid content of the leaves with small stems attached from the different varieties of tomatoes.

The variety of *Datura stramonium* used does not appear to have a definite relation to the amounts of alkaloids translocated from the root-

TABLE I—TOTAL ALKALOIDS IN THE LEAVES AND SMALL STEMS OF THREE VARIETIES OF TOMATOES AT VARIOUS STAGES OF GROWTH GRAFTED ON TWO VARIETIES OF *Datura Stramonium* ROOTSTOCKS*

Date of Harvest	Variety	Percentage of Total Alkaloids When Grown on	
		Green-stem *Datura Stramonium*	Purple-stem *Datura Stramonium*
Jun 20	Marglobe	0.087	0.116
	Columbia	0.058	0.116
	Golden Jubilee	0.173	0.162
Jun 29	Marglobe	0.153	——
	Columbia	0.153	——
	Golden Jubilee	0.219	——
Jul 9	Marglobe	0.133	0.145
	Columbia	0.145	0.120
	Golden Jubilee	0.190	0.140
Jul 20	Marglobe	0.060	0.070
	Columbia	0.090	0.170
	Golden Jubilee	0.090	0.100
Aug 18	Marglobe	0.156	0.133
	Columbia	0.090	0.161
	Golden Jubilee	0.144	0.179

*Assay of similar material harvested on the dates indicated from tomato plants grown as controls gave negative results.

stock to the tomato foliage. However, more vigorous growth of herb was made by all three tomato varieties on the green-stem stramonium rootstock. All samples harvested for assay on July 20 showed a low alkaloid content. The reason for this is not apparent but the extremely heavy rains that fell during the month may have been a factor. On the above date two entire Marglobe plants growing on the green-stem stramonium were removed, composited and the several plant parts assayed. The leaves and small stems contained 0.12 per cent total alkaloids and the large main stems 0.10 per cent. The root of the stramonium on which the tomatoes were grafted contained 0.33 and graft scar tissue 0.04 per cent. On September 7 three Marglobe plants growing on the purple-stem stramonium were harvested and the plant parts assayed separately for comparison. The leaves and small stems of these three plants contained 0.13, 0.09 and 0.13 per cent total alkaloids respectively; the large main stems 0.09, 0.08 and 0.09 per cent, and the roots of the three stramonium plants on which the tomatoes were grafted contained 0.10, 0.09 and 0.17 per cent. Parts of individual plants harvested at Auburn, Alabama in November 1944 gave similar results. All parts of two control plants contained no alkaloids while the leaves and small stems of two plants grown on stramonium rootstock showed, respectively 0.11 and 0.37 per cent, the large stems 0.08 and 0.16 per cent of total alkaloids. The roots of the two stramonium plants on which these plants were grown contained 0.08 and 0.14 per cent of total alkaloids. It appears from the data obtained that there is considerable variation in the alkaloid content of the foliage from individual grafted plants. It is, therefore, quite reasonable to assume that the fruit from individual plants may also vary in alkaloid content. This was not, however, verified by tests.

The data in Table II on the results of the alkaloidal assay of fruit samples variously treated show a wide variation in total alkaloids present. This may be due to different amounts of alkaloids being present in the fruit when harvested or to the destruction of alkaloids in the treatment before assay or during the assay process. Since the fresh fruit contains about 93 per cent moisture, the solids are concentrated about 14 times on dehydration, which under certain conditions may cause the decomposition of some of the alkaloids present. Frequently high alkaloid content was indicated when the fruit was extracted in the fresh state or in the partially dehydrated condition but because of the formation of emulsions in the assay process concordant results could not be obtained. From the data it appears that lower percentages of total alkaloids were found when samples representing substantially

TABLE II—RESULTS OF ASSAYS OF FRUIT FROM TOMATO PLANTS GRAFTED ON STRAMONIUM ROOTSTOCK, PULPED AND SUBJECTED TO VARIOUS TREATMENTS AS INDICATED*

Variety and Maturity of Tomato; Variety of Stramonium Rootstock (Green Stem and Purple-Stem)	Date of Harvest	Quantity of Fresh Fruit Assayed (Gm)	Treatment of Fresh Fruit and Materials Added in Preparation for Assay	Total Alkaloids Per Pound of Fresh Fruit (Mg)
			Marglobe	
Mature				
Green-stem	Jul 20	300	Oven-dried, 60°C	6.54
			30 gm Plaster of Paris; oven-dried, 60°C	7.92
			30 gm gypsum, oven-dried 60°C	7.80
			30 gm hydrated lime**	6.50
	Aug 5	300	30 gm gypsum; oven-dried, 60°C	6.24
			30 gm gypsum; 20cc ammonia; oven-dried, 60°C	9.36
			30 gm Plaster of Paris; oven-dried, 60°C	6.32
			30 gm gypsum, 20cc ammonia, evaporated to paste	13.00
			30 gm gypsum; 20cc ammonia†	10.49
			10 gm filter-cel, 300 gm. H_2SO_4 (2.5 per cent)‡	8.67
		500	50 gm Plaster of Paris; evaporated to paste	5.20
			50 gm gypsum; evaporated to paste	3.47
Purple-stem	Aug 5	500	50 gm Plaster of Paris; oven-dried, 60°C	4.33
			50 gm gypsum; oven-dried, 60°C	3.47
Immature				
Green-stem	Aug 5	300	30 gm Plaster of Paris; oven-dried, 60°C	6.32
Purple-stem	Aug 5	300	30 gm Plaster of Paris; oven-dried, 60°C	6.20
			Columbia	
Mature				
Purple-stem	Jul 27	630	63 gm Plaster of Paris, oven-dried, 60°C	3.30
Green-stem	Jul 27	630	63 gm Plaster of Paris; oven-dried, 60°C	4.46
	Aug 5	500	50 gm Plaster of Paris; oven-dried, 60°C	5.63
Immature				
Green-stem	Aug 5	300	30 gm Plaster of Paris; oven-dried, 60°C	5.47
			Golden Jubilee	
Mature				
Purple-stem	Jul 27	2,370	237 gm Plaster of Paris; oven-dried, 60°C	1.77§
Green-stem	Aug 5	500	50 gm Plaster of Paris; oven-dried, 60°C	4.33
Immature				
Green-stem	Aug 5	500	50 gm Plaster of Paris; oven-dried, 60°C	3.87

*Immature and mature fruit from plants grown normally as controls, dried with Plaster of Paris at 60°C and assayed gave negative results.

**Extracted as such by shaking with ether.

†Extracted as such by shaking with chloroform.

‡After shaking 4 hours a 400 gram aliquot was filtered off and extracted with successive portions of chloroform.

§Extraction of alkaloids probably not complete.

more than 300 grams of fresh fruit were assayed. This may be due to the fact that it was very difficult to get penetration of ammonia into the bulky, dry powdered mass of highly acid material for the release of the alkaloids. The small amount of moisture introduced with the ammonia caused the formation of very small gummy pellets of some of the finely divided powder which resisted penetration by the solvents. As shown in the Table II, the highest indicated alkaloid content was obtained on three 300-gram samples of mature Marglobe fruit harvested on August 5. To each pulped 300-gram sample 30 grams of gypsum were added and the acids neutralized with 20 cubic centimeters of strong ammonia. One of the samples was then evaporated to dryness, before assay, another was evaporated to a paste, and the third was extracted with chloroform without previous concentration.

The solutions of the fruit extracts that were titrated were also checked for the presence of alkaloids by purification of the titrated residue and testing with Mayer's reagent or by the nitric acid-alcoholic potassium hydroxide color test for atropine. In all cases where alkaloids were indicated by titrimetric determination Mayer's reagent or the colorimetric tests always gave positive results. All control samples from the normally growing tomatoes gave negative results by titration and with either Mayer's reagent or the colorimetric test. When a purified tomato extract, shown by assay to contain 6.40 milligrams of total alkaloids per pound of fresh fruit and a prepared atropine solution of similar strength were compared by the use of Mayer's reagent the tomato extract showed definitely the heavier precipitate.

The various tests above described prove definitely that tomato fruit from plants grafted on stramonium may contain considerable quantities of alkaloids. The results, however, are not conclusive regarding the actual amounts of alkaloids that may be present in the fruit under all conditions. In Table II it will be noted that the lowest indicated alkaloid content is 1.77 milligrams per pound of fresh fruit and the highest 13.00 milligrams. The lower figure obtained by extracting by percolation a dried sample representing 2,370 grams of fresh fruit, no doubt indicates incomplete extraction. The higher figure resulted from the assay of a partially dehydrated sample representing 300 grams of another variety gown on a different variety of stramonium rootstock and harvested at a later date. The preparation of the sample for assay by a procedure that will not cause the loss of alkaloids requires further study. Until a satisfactory method is found the relation of variety and maturity of the fruit, seasonal conditions, and other factors on alkaloid content cannot be determined.

Although the presence of alkaloids in the fruit, leaves and small stems of tomatoes grafted on stramonium was demonstrated by chemical assay and by alkaloidal reagents it seemed desirable to have the same material tested biologically through the collaboration of the Division of Pharmacology, Food and Drug Administation, Federal Security Agency as already mentioned. Purified extracts were prepared from the pulped fruit mixed with plaster of Paris and dried as in the chemical assay method described. Samples representing

2,368 grams of fresh fruit were extracted by maceration and percolation with an ether-chloroform solution made strongly alkaline with ammonia, and the combined extracts and washings evaporated to a small volume for purification by the assay method. One-fourth of each of the purified extracts were used for the titrimetric determination of the alkaloids present and the remaining three-fourths of each were made up to 10 milliliters with distilled water and sufficient 0.02 normal sulfuric acid to convert the alkaloids present to the sulfates. This solution was used for the bioassay. Extracts were also prepared in the same manner from leaves and small stems of both grafted and control plants using 20-gram samples of the dried material. One-half of each extract was used for the titrimetric determination of the alkaloids and the other half made up to 10 milliliters for bioassay.

In Table III the material tested is described and the chemical and pharmacological data listed. In reporting the results of the bioassay Mr. Geoffrey Woodard stated as follows:

> "The eyes of a series of dogs were first treated with atropine sulfate in concentrations of 1 : 100 to 1 : 1,000,000 in tenfold dilution steps to obtain a base line for comparison. Two hours later the degree of mydriasis and accommodation to a standard light source were noted for each concentration. The concentration giving positive but submaximal effects was 1 : 10,000.
>
> Each of the samples submitted was diluted ten times with water and tested in one eye of each of two dogs per sample.
>
> It should be pointed out that this test is not an accurate bioassay but indicates that the solutions have biological activity roughly equivalent to their chemically determined alkaloid content."

TABLE III—DETERMINATION OF MYDRIATIC EFFECT OF EXTRACTS OF PARTS OF TOMATO PLANTS GROWN ON STRAMONIUM ROOTSTOCK IN COMPARISON WITH THE ALKALOID CONTENT OF SUCH EXTRACTS AS DETERMINED BY CHEMICAL ASSAY

Extract No.	Source of Extracts*	Parts Total Alkaloids Per 10,000 of Solution Used in Bioassay**	Average Effects†	
			Mydriasis	Accommodation
1	Marglobe—Mature fruit—grafted	1.5	++	+
2	Marglobe—Green fruit—grafted	0.69	++	+
3	Marglobe—Mature fruit—control	0.00	—	—
4	Golden Jubilee—Mature fruit—grafted	0.69	++	+
5	Marglobe—leaves and stems—grafted	1.33	++	++
6	Marglobe—leaves and stems—control	0.00	—	—
	Atropine sulfate (standard)	1.00	++	++

*Extracts 1 to 4 prepared from equal quantities of fresh fruit. Extracts 5 and 6 prepared from equal quantities of leaves and small stems.

**Total alkaloids in the extracts referred to in footnote * as determined chemically.

†— = negative, + = slight, ++ = moderate, +++ = maximum.

The bioassays support the conclusions that may be drawn from the chemical assays that the mydriatic alkaloids of stramonium pass from the rootstock of that plant to the stems, leaves and fruit of the tomato plan grafted thereon. Although the concentration of alkaloids in the fruit thus grown apparently varies greatly and is probably influenced by various factors not understood at this time it is obvious that under some conditions a serious menace to health could be involved. As has been pointed out, the average person would not likely associate illness caused by these alkaloids with the eating of tomatoes. This fact is a futher element of danger. The experimental evidence justifies the conclusion that: (a) the poisonous mydriatic alkaloids are present in tomato fruit grown on stramonium rootstock; (b) the quantity present varies greatly; and (c) the probability of being seriously or fatally poisoned by this means is relatively remote when normal amounts of the fruit are eaten but the possibility of serious consequences resulting from the use of such fruit should be recognized.

SUMMARY

In the South, nematode injury to tomato plants is so severe that in some localities they can be grown only with difficulty. For many years it has been a practice to a limited extent to graft the tomato plant on the rootstock of *Datura stramonium* (stramonium, jimson weed) which is not subject to nematode injury. The grafting is easily accomplished and the tomato plant grows well and produces excellent fruit on the stramonium rootstock.

Since stramonium contains potent alkaloids which, according to several investigators, are produced in the roots and are transferred to the grafted tomato plant an investigation was made of the extent to which this may be expected and the health hazard involved in the consumption of tomato fruit thus grown.

Several varieties of tomatoes were grafted on both the green-stem and purple-stem forms of *Datura stramonium* and the fruit, leaves and small stems analyzed for alkaloid content in comparison with corresponding parts of the plant grown normally as controls.

The alkaloid content of the fruit from grafted plants ranged from 1.77 to 13.00 milligrams per pound of fresh fruit and varying amounts were found in the leaves and small stems. The wide range is in part explained by the difficulty of extracting the alkaloids but apparently several factors such as variety, cultural conditions and maturity are involved.

Biological tests were made of the extracts of the fruit, leaves and stems by determining the degree of mydriasis obtained in dogs. The results in a general way indicated a concentration of the alkaloids in the extracts similar to that found by chemical assay.

It is concluded that: (a) when eating tomatoes from plants grafted on stramonium rootstock some of the poisonous stramonium alkaloids are ingested; and (b) when normal quantities are eaten the probability of being seriously or fatally poisoned are probably remote but the possibility of serious consequences following the use of such fruit under certain conditions must be recognized.

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Sapsucker Injury to Trees on Home Grounds, 1938–46

By T. J. Talbert, *University of Missouri, Columbia, Mo.*

The yellow-bellied sapsucker *(Sphyrapicus varius)* began to do injury to new plantings, particularly the Scotch Pine *(Pinus sylvestris)* Austrian Pine *(Pinus nigra austriaca)*, and the Jack Pine *(Pinus banksiana)* in about 10 to 12 years after planting. As the trees grew older the damage became increasingly severe but was largely confined to the species of pines mentioned above. None of the trees were killed but all were noticeably weakened. The damaged areas were rough, knotty, and bulging in appearance. They were also disfigured and smeared badly through the exudation of resin.

Other so-called evergreens were growing on the grounds when the sapsucker began its damage. There was, however, little or no injury to them during any year. Furthermore, a long list of deciduous trees, shrubs, and vines were growing during the same period on the grounds and there was practically no injury to be found on any of the different specimens.

CHARACTER OF INJURY

The damage done by the yellow-bellied sapsucker consists usually of concentric rings or circles of holes through the bark and into the sapwood. The rings of holes usually extend all the way round the trunk or large branch. In width up and down the tree trunk or branch, the injured area may vary from 2 or 3 inches to as much as 5 or 6 inches. The bands of rings of small holes, 1/8 to 1/4 inch in diameter, and about the same distance apart, are often made just beneath branches. The distance between bands or rings will vary from a few inches to 8 to 10 inches or more. When the injury is severe rectangular areas of injury 1 inch or more in length and nearly 1/4 inch wide extending lengthwise with the trunk, may accompany and be mixed with the concentric rings of holes.

SEASON OF SAPSUCKER INJURY

At Columbia, Missouri, which is located near the center of the state, injury generally starts between February 15th and March 1st. It is continued over a period of about 3 or 4 weeks. The damage is apparently done early in the annual sapsucker migration period.

CONTROL MEASURES EMPLOYED

Use of Firearms:—During the first 2 or 3 years the rifle was used to frighten away the seemingly few sapsuckers responsible for the feeding damage. This procedure did not appear to stop or slow up the occurrence of belts or rings of injury on the trunks of the largest pine trees.

Wrapping Methods:—For the following 3 years strips of gunny sacks 6 to 8 inches wide were wrapped around the trunks and largest branches. These proved effective for the portions covered but frequently injury was done above or below the wraps. The job of wrapping was a difficult one and unless the wraps were removed they tended to mar the appearance and beauty of the trees.

Sprays and Spraying:—Finally in 1942 it was believed that spraying might prove effective. The first application made consisted of lead arsenate alone. On account of bad weather conditions near the middle of February, the proper time for the spray application, work was delayed until March 1. The spray while not entirely effective appeared to be of value. Half or more of the injury was done, however, before it was made. Somewhat similar results with the same spray mixture were secured the second year, 1943, from spraying work. Again it was not entirely satisfactory but the work seemed promising and more effective in preventing tree injury.

The following year, 1944, a spray consisting of Bordeaux 3–4–50 plus 1 pound of lead arsenate was used about February 10th. The equipment employed was somewhat better than that used in 1942 and 1943. It consisted of a small wheel barrow sprayer, 12 feet of hose, and extension rod about 3 feet long equipped with an angle disc type of nozzle.

The pine trees on which the spray was applied ranged from 12 to 15 feet in height and spread. It was, therefore, rather difficult to do a thorough job of spraying and cover the trunks and large branches properly from within a few feet of the ground to within about 3 or 4 feet of the tree tops and ends of the large branches. A fairly satisfactory coverage, however, was obtained in spite of the difficulties encountered.

After the application of this spray, the sapsucker injury fell off markedly and the value of the work was very evident. Injury did continue to show up but it was not serious and it appeared to be confined largely to sections or portions of the trunks and branches that were not thoroughly or adequately covered by the spray.

EFFECTIVE EQUIPMENT AND SPRAY

From the spraying experience obtained in the three previous seasons (1942–43, 1943–44, and 1944–45) it seemed obvious that with thorough spray coverage, the use of the right mixture of bordeaux and lead arsenate, and the application made at the proper time good control was possible. Consequently, for the spraying work of 1946 a larger barrel pump type of sprayer equipped with an adequate length of spray hose, 8 foot extension rod, and a regular orchard disc type of nozzle was secured.

The spray mixture used consisted of bordeaux 6–6–50 and 3 pounds of lead arsenate. An extra effort was made to cover properly all trunks and branches that might be subjected to the attack. Furthermore, the application was made promptly upon the first sign of injury which was on February 10, 1946.

The results obtained from this application appear to be all that one has a right to expect. Only a few scattered holes were found on the trees after several careful inspections. Some trees that had shown the most injury in the past were entirely free from further attack following the spray application.

TREE INJURY AND RECOVERY

The tree injury accumulated up to the year 1945 appeared serious for 10 of the largest pine trees. This was true because the trunks and large branches were more than half girdled. That is, the bark and cambium was completely killed in an area of more than half the distance around trunks and branches. With no injury occurring this year and very little last year the wounds of earlier years appear to be healing rapidly and all indications point to a fairly rapid recovery.

Response of the Lowbush Blueberry to Fertilizers

By W. W. Smith, Russel Eggert, A. R. Hodgdon, and A. F. Yeager, *University of New Hampshire, Durham, N. H.*

Producers of lowbush blueberries in New Hampshire who have been in the business 50 years or more, have observed that the yield of fruit on older areas has gradually declined from 60 or more crates per acre near the beginning of the period to 10 crates or less at the present time. It is also observed that the yields on new areas that have been in production 10 or 15 years are often higher than the yields on similar areas that have been in production over 50 years in spite of the fact that the older areas have a more complete coverage of plants.

The plant growth in some of these old blueberry pastures is so weak that it is difficult to get a satisfactory burn. It is a common practice in some commercial fields in Maine to spread hay on the blueberry plants in order to get a clean burn. Most of the good blueberry pastures in New Hampshire, however, are at high elevations on mountain slopes where the cost of spreading hay is prohibitive.

Chandler and Mason (6), in experiments on pruning of the lowbush blueberry have pointed out that burning stimulates the blueberry plants more than cutting off the stems. Apparently, as yet, there is no satisfactory substitute for burning of the lowbush blueberry to maintain production.

Examination of the surface soil from high producing areas has shown it to be composed of a 1-inch duff made up largely of roots, dead and decaying twigs and leaves, while an examination of the surface soil of the low producing areas shows the layer of duff missing or very thin. It is common practice in blueberry areas in New Hampshire to burn once in 3 years, and an area that has been in production for 60 years may have been burned as many as 20 times, which, because the duff is inflammable, and accompanied by normal decomposition, probably is responsible for the low organic content of this soil. There is no consistent difference in soil acidity between the high and the low yielding areas. Both are around 4.5. The plants on the low yielding areas are much shorter and a lower proportion of the stem forms fruit buds.

These conditions of low blueberry yield and weak plant growth have led to investigations to determine the reasons for that decrease and to find methods of reinvigorating weakened areas of low yielding plants to their former productive state.

Chandler and Mason (5), found complete fertilizers gave a greater increase in yield of fruit on blueberry land in Maine than did combinations using only two elements. They also pointed out that on many plots weed growth was stimulated to such an extent that the competition for light and nutrients resulted in a decrease in the blueberry yield. Chandler (4), working with the Maine lowbush blueberry, stated that the yield of most blueberry land is reduced when fertilizer is applied because weeds are stimulated to rapid development and shade the blueberry plants.

Beckwith and Coville found that applications of nitrate of soda did not materially increase the yield, while a mixture of nitrate of soda, acid phosphate, and potash doubled the yield of cultivated blueberries growing in New Jersey.

Bailey and Franklin (1), working in Massachusetts, state that with cultivated blueberries nitrogen generally has the most effect on both the growth and yield but experiments in New Jersey indicate complete fertilizer is more desirable because nitrogen used alone causes excessive shoot growth.

It would seem from these results, that fertilizers might be applied to the blueberry field with three objectives in mind; (a), of maintaining production for a greater number of years before it became necessary to burn off old and weakened tops of plants and thus destroy accumulated organic matter; (b) to increase plant and grass growth so that a burn could be obtained without hauling hay onto the area; (c) to increase the yield of the blueberries themselves. With this idea in mind, over 100 fertilizer plots were set up on different blueberry pastures in the state. Most of these plots were on older, low yielding pastures. Areas were selected which had been burned the year before; 2 years before, and three years before, respectively. It was thought there might be an ash residue that contributed to the stimulation and some materials such as wood ashes, charcoal, and lamp black were included in the trial plots.*

Table I lists the different materials applied during 1942, 1943, and 1944 which have failed to give any beneficial results to date.

TABLE I—MATERIALS BROADCAST ON LOWBUSH BLUEBERRY SOILS WITH NO VISIBLE RESULTS—1942, 1943, 1944

Plots Treated	Material	Pounds Per Acre
2	Phosphoric acid	500, 550
3	Muriate of potash	250, 550, 550
4	Hydrated lime	250, 500, 1000, 2000
1	Potassium sulphate	200
3	Sulphur dust	650, 1300, 2000
1	Lamp black	200
3	Wood charcoal	800, 1600, 1600
3	Wood ashes	2000

Chandler (3), obtained increased yields with applications of lime on lowbush blueberry land in Maine. The yield of fruit on the plots in New Hampshire was negligible both in check and treated plots and records of yields could not be taken. However, an examination of the plants themselves showed no difference between check and treatments.

In a low yielding field of 3-year-old tops sulphate of ammonia applied at the rate of 500 pounds per acre in May, 1943, produced vigorous growth as did September applications of equal amount, but neither the spring nor the fall applications of that material resulted in an appreciable increase in yield in 1944. However, a complete fertilizer of 7–7–7 analysis applied at the rate of 500 pounds per acre in May 1943, produced at the rate of 81 24-quart crates per acre in 1944, compared with no yield on the adjoining check plot. An apparent residual effect of this material resulted in a vigorous growth in 1944 and a further production of 53 cases per acre in 1945, compared with two on the check plots. New growth in 1945 is still sufficiently vigorous to indicate the production of a large crop in 1946.

On June 29, 1944, plots with control plots between them were laid out on low yielding blueberry land, last burned in 1941, and treated with nitrate of soda and a complete fertilizer. The applications and the 1945 yields are shown in Table II.

TABLE II—Yield of Blueberry Plots Treated With $NaNO_3$ and 7–7–7 Fertilizers, June, 1944.

Material	Pounds Per Acre	Number of 24-Quart Crates Per Acre
$NaNO_3$	200	10.8
Check	--	12.7
	500	27.2
	--	21.8
	1000	36.3
	--	22.7
7 7 7	200	47.1
Check	—	24.5
	500	45.3
	—	24.5
	1000	47.1
	—	19.0

Two hundred pounds per acre of 7–7–7 fertilizer applied in 1944 was effective in developing fruit buds in 1944, and producing 47 crates per acre in 1945. However, the new growth produced in 1945 on these plots was insignificant and does not appear sufficiently vigorous to develop a crop in 1946. The 1000 pound application not only developed a crop of 47 crates per acre in 1945, but also produced a vigorous vegetative growth (Fig. 1). All plots treated with 7–7–7 fertilizer were much more productive of fruit than those to which nitrate of soda was applied. Applications of nitrate of soda at the rate of 200 pounds per acre, which is equivalent in nitrate to 500 pounds per acre of 7–7–7, stimulated weed growth with no increase in yields (Fig. 2).

Nitrate of soda at rates of 500 and 1000 pounds per acre produced heavy growth of grass and weeds as well as blueberry tops. The 1000 pound application developed so much vegetation that it was difficult to harvest the fruit (Fig. 3).

Shoots were selected at random on May 24, 1945, from unfertilized plots, from plots treated with 1000 pounds of 7–7–7 fertilizer, and from plots treated with 1000 pounds of ammonium sulfate in 1944. Total length of growth and length of fruiting area was measured, and the number of fruit-bud clusters and fruit blossoms per cluster were counted. The effects of ammonium sulfate and 7–7–7 fertilizer on shoot growth, on the development of fruit buds and blossoms and on yield of fruit are shown in Table III.

Both fertilizers increased the shoot growth, the fruiting area of the shoots, and the number of blossoms per shoot.

It can be noted that ammonium sulfate application stimulated more shoot growth but less fruiting area than did a complete fertilizer.

At the time of harvest on July 24, 1945, fruiting shoots were selected

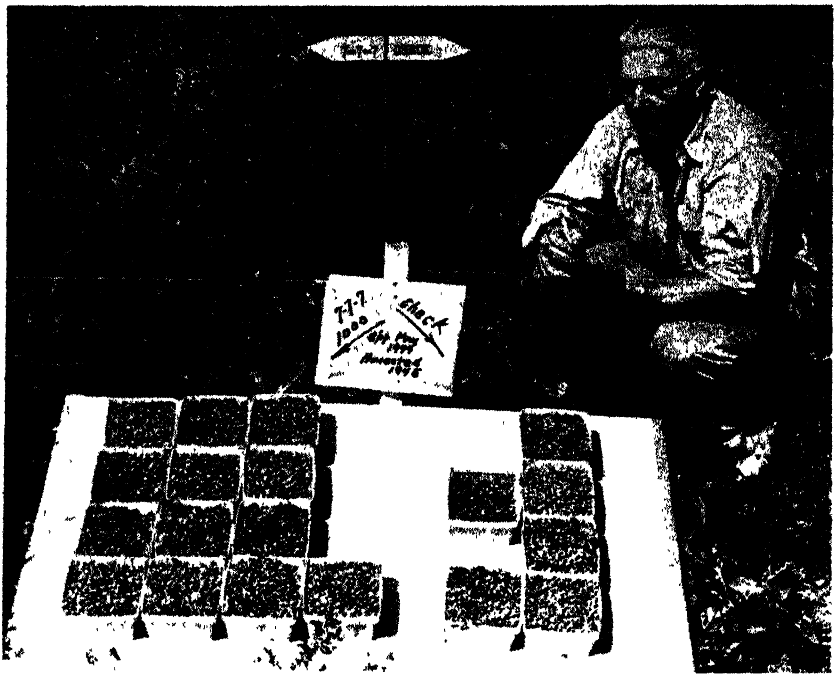

FIG. 1. Application of 1000 pounds per acre of 7-7-7 fertilizer doubled the blueberry yield on these plots. It also increased weed growth as can be seen in upper left as compared to untreated area in upper right.

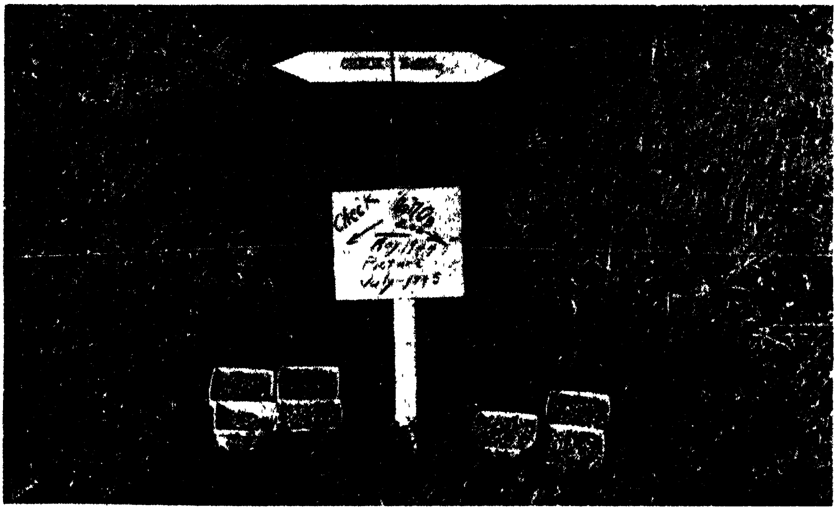

FIG. 2. Two-hundred pounds per acre of nitrate of soda increased weed growth (see upper right of photo), and did not increase blueberry yield on these plots.

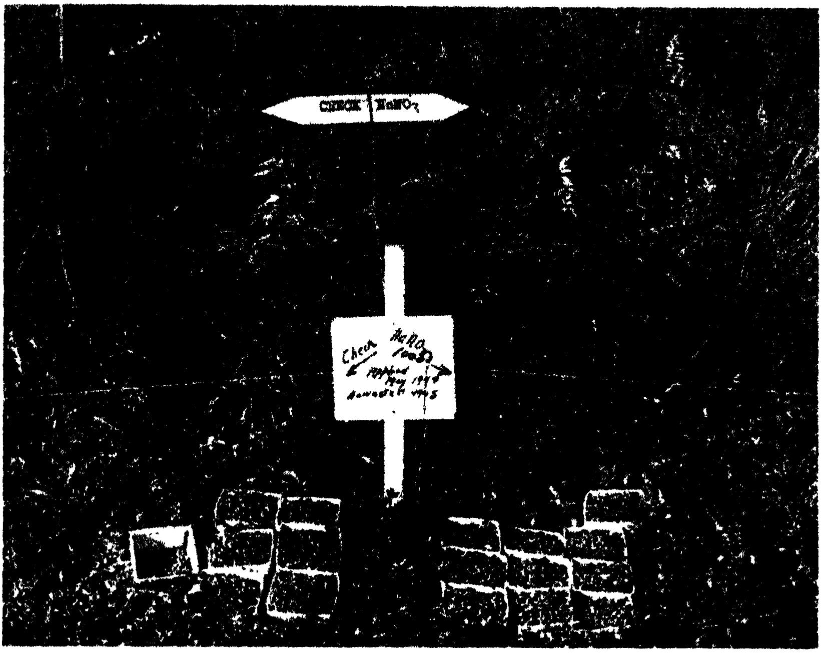

FIG. 3. One-thousand pounds of nitrate of soda per acre increased berry production and stimulated objectionable weed growth. (See upper right.)

TABLE III—EFFECT OF FERTILIZERS ON SHOOT GROWTH AND FRUIT BUD DEVELOPMENT OF LOWBUSH BLUEBERRY PLANT GROWTH ON LOW YIELDING BLUEBERRY LAND THIRD YEAR AFTER BURNING. 1000 POUNDS PER ACRE APPLIED JUNE 29, 1944.

Plant Part	Ammonium Sulfate (Inches)	Check	7-7-7 Fertilizer	Check
Shoot growth*	8.8	4.6	6.1	5.2
Fruiting area	0.9	0.4	2.4	0.8
Fruit bud clusters (number)	3.7	2.7	—	—
Blossoms per cluster	5.9	3.9	—	—
Blossoms per shoot	21.8	10.7	23.7	5.5
	Burned 1942			

*Average of shoots cut at random from each plot, May 24, 1945.

from treated and check plots, the berries on each were counted, and the fruits weighed and tabulated in Table IV.

These data indicate no difference in time of ripening due to treat-

TABLE IV—NUMBER AND WEIGHT OF FRUITS FROM FERTILIZED AND UNFERTILIZED BLUEBERRY PLOTS

Treatment	Average Number Fruits Per Shoot			Average Weight Per Fruit in Ounces
	Green	Ripe	Total	
Fertilized	1.42	9.35	10.77	0.0093
Check	0.67	4.65	5.32	0.0094

ment, and that size of fruit was not affected by the treatment, but that the increase in yield is due to greater number of berries.

SUMMARY

1. May and June applications of 7–7–7 fertilizer at the rates of 200, 500, and 1000 pounds per acre, respectively, have greatly increased the yield of lowbush blueberries.
2. Increased yield on fertilized plants appears to be due primarily to larger numbers of fruit-bud clusters and more fruit buds per cluster.
3. Application of the complete fertilizer to plants with 3-year old tops lengthened their productive period from 3 to 5 years, and possibly 6 years.
4. Nitrate fertilizers alone applied at the rate of 200, 500, and 1000 pounds per acre produced excessive growth of weeds and grass as well as blueberry stems, with a slight increase in yield of fruit.

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California Vineyard Fertilizer Experimentation

By W. O. WILLIAMS,[1] *University of California, Davis, Calif.*

THE miscellaneous data available at the time these experiments were initiated indicated that yield response to potash and phosphate in California vineyards would probably be rare. Pot tests, plant tissue, and soil analysis should theoretically reveal vineyards wherein deficiencies of potash and phosphate are most likely to occur. It seemed obvious, however, that a randomized distribution of test plots in the major vineyard areas would be much more useful in supplying California vineyardists with information as to the likelihood of economically favorable response in their vineyards. General data seemed to be most urgently needed to prevent undue emphasis on isolated cases of response such as Ulrich has reported (1) for potash.

The analytical studies of vine tissues are to be presented in a subsequent report. It appears, however, that if the test plots had been located only in vineyards having low nitrate in the petioles, a number of cases which have responded to nitrogen applications would have been overlooked. In fact, yield responses have been obtained even where extremely high nitrate concentrations occurred in the petioles.

It seems to the author that the tendency to minimize presentation of data, particularly when the results are negative, should be avoided. Accordingly, the data herein are presented extensively, although the results are largely negative. Further, for the convenience of the reader, the details of sampling, etc., are repeated (2).

Considering that responses to potash and phosphate applications are likely to be rare, it has seemed most economical of effort and expense to test the vine response to nitrogen (N) alone and in combination with phosphate and potash (NPK). If the combined fertilizer results in additional response over that of nitrogen alone, further tests are to be instituted to ascertain the relative effectiveness of the potash (K) and phosphate (P).

Practical difficulties have prohibited the use of randomized blocks or Latin square methods of error control in these cooperative test plots. Theoretically, however, comparison of an elongated fertilized row with the average of two check rows, one on either side, should largely compensate for soil variation in both directions. Further in order to compensate partly for variations induced by cultural operations, particularly pruning and thinning, check and fertilized lots of vines alternated in the rows provided the rows were sufficiently long. The results were statistically evaluated by Student's pairing method (3).

The cooperating vineyardists have been asked to have one man do the pruning etc., since the variations introduced by slightly different techniques may often exceed differences resulting from the fertilizer treatments. Two instances have occurred which point to the advisability of this requirement in order to avoid unnecessary variability. In one test plot the guard rows, which are retained between the fertilized and check rows in all cases, yielded 12 per cent more than did the fertilized and 19 per cent more than the check lots. The guard rows had been pruned later by another individual (the check and fertilized lots are pruned and weighed in advance to prevent mixing of the prunings). In another plot the average of the fertilizer plot treatments and of the checks all indicated a yield of 30 per cent less in 1945 than in 1944, whereas the cooperator's records showed 12 per cent increase in the surrounding vineyard. Although in both instances actual data are lacking, it appears evident that the man pruning the test lots of vines left somewhat shorter spurs than did the rest of the pruning crew. Winkler (4) has reported the marked effect of pruning (and thinning) variation on yield.

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[1] The generous assistance of N. D. Hudson, A. D. Rizzi, J. L. Quail, H. G. Rodgers, A. G. Volz, C. H. Swanson, H. J. Baade, and H. A. Weinland of the Agricultural Extension Service is gratefully acknowledged.

Potash and phosphate are commonly fixed, particularly in heavier soils (5) deficient in these elements. Extremely high K application (6) appeared to be necessary for fruit trees on potash-deficient soils. For this reason, an application rate was selected which ordinarily is well beyond practical applications. It appears necessary to obtain an increased absorption, which is demonstrable by tissue or other analyses, before one can be sure that nonresponse to the application of a particular fertilizer has not resulted from soil fixation.

For the NPK treatments 1 pound treble superphosphate (44 per cent P_2O_5), 1½ pounds of potassium sulfate (51 per cent K_2O), and 1 pound of ammonium phosphate (16 per cent N, 20 per cent P_2O_5) were applied to each vine. The N treatment consisted of ¾ pound of ammonium sulfate per vine. It is to be noted that the NPK mix contained appreciably more sulfate than did the N treatment, hence if sulfur response should occur the NPK mix would be favored. Most of the table- and raisin-grape vineyards approximate 450 vines to the acre, whereas the wine grapes mostly range from 540 to 680 vines. The fertilizer was applied in bands in deep furrows in 1941 and thereafter, except in a few instances, drilled about 10 inches deep with a fertilizer machine designed for experimental plot work (7). The bands were located about 2 feet out on both sides of the vine row. It seems probable that the deep placement and the breaking off of a certain number of roots would establish favorable conditions for new root growth and facilitate active absorption in a zone about the band wherein the fixation power of the soil must be saturated, at least temporarily. The applications were ordinarily made in March or the first part of April about the time new shoot growth appears.

Box or raisin tray counts served for crop records. Large signs placed at the beginning and end of each treatment were used as temporary recording points, particularly in the table-grape vineyards, which are commonly picked over two to four times.

Shortly prior to harvest, samples consisting of enough clusters to fill approximately a 28-pound box were taken by removing the first convenient, approximately normal cluster from a particular section of each vine in each replication. The sample clusters were removed without knowledge of the treatment in order to obtain an unbiased sample. The clusters were counted and weighed in order to obtain an average cluster weight. Small sections were clipped out of the top, middle, and bottom of each cluster. The berries from these sections were removed from the stems, and two lots of 200 berries were counted and weighed in order to find the average berry size. If reasonably close checks were not obtained, further lots were counted. In the case of colored varieties, one kilogram of the berries was weighed out for color extraction. These berries were placed in a 6-liter flask and 1 liter of 20 per cent ethyl alcohol, 0.1 normal in HCl, was added. The flasks were placed on electric hot plates regulated so that the solution boiled in 20 minutes and simmered at low heat for 15 minutes. A suitable aliquot of the cooled and filtered extract was acidified with 2 ml of 1 + 1 HCl and diluted to 100 ml. A modified Evelyn photoelectric colorimeter, with Eastman Kodak Company No. 430 and 338 filters, served to determine the color density. No absolute standard was utilized, as the figures are used only comparatively.

The juice was extracted from the cluster residues and a Balling hydrometer used to ascertain the soluble-solids content of the juice. The acidity was determined by titrating a 10-ml aliquot of the juice with 0.133 N NaOH with phenolphthalein as the indicator.

The prunings from each replica lot were collected and weighed, as these weights should give an accurate measure of the vine growth, since a very high percentage of the new shoot growth is removed each year at pruning time. The small increments in annual circumference increase of the older vines, together with the difficulties introduced by bark loosening, make trunk measurements somewhat unsatisfactory.

Results and Discussion

The data presented in Table I are all expressed as the percentage increase (+ figures) or decrease (— figures) of the fertilized plots over or under the check plots. Thus the figure of +19.2 means that compared to a check yield of 100 the fertilized yield was 119.2.

The result of averaging the N treatment data from Table I indicates a statistically significant yield increase of +9.9 per cent as the result of N application. Since there was no NPK treatment in Hummel's Green Hungarian plot, these data were not included in the average in order to allow a direct comparison of plots receiving both N and NPK treatments. It appears that the addition of P and K has depressed the effect of the nitrogen, since the average yield increase for the NPK treatment was only +7.2 per cent greater than the check. In general, the nitrate content of the petioles was lower in the NPK treated vines than the N alone. Although anionic competition may be limiting the nitrogen absorption, it seems likely that the stimulating effect of phosphates such as Fred and Hart (8) have reported may have induced sufficient bacterial growth to absorb a portion of the N. The relative ease of movement after nitrification of nitrate compared to phosphate would seem to argue against an anionic competition explanation.

In a few instances, the NPK treatments have apparently yielded noticeably more than the nitrogen alone. George's Sultanina plot is the only case in which this result was fairly consistent. It appears that the yields from the NPK treatment in this case were increasing faster than did those due to the N effect; however, the plot contained only

TABLE I—COMPARISON OF FERTILIZER TEST PLOTS, 1941–1945. EXPRESSED AS PERCENTAGE CHANGE FROM THE CORRESPONDING CHECK LOTS

Cooperator Soil Type* Variety	Years Fertilized	Yield		Color		Balling		Acid		Berry Size		Weight of Prunings	
		N	NPK	N	NPK	N	NPK	N	NPK	N	NPK	N	NPK
Mendocino County													
Salinger	1942	+19.2	*+9.4*†	−8.5	−15.7	−5.0	*−7.2*	+6.0	+5.1	*−10.4*	−8.5	*+28.7*	*+18.7*
Pinole g. l.	1943†	+22.4	+42.0	−1.4	−2.4	−4.1	+16.0	+2.5	−1.3	−0.6	−10.7	*+24.9*	*+20.2*
Carignane	1944†	*+88.0*	+75.0†	+0.5	+0.3	−6.1	−6.1	+10.6	+9.5	−3.7	−7.8	*+71.0*	*+69.0*
Sonoma County													
Sink	1943	+9.7	+6.9	−0.5	−2.6	−0.5	−2.4	+2.3	+4.6	+2.9	+4.8	+5.6	+4.3
Aiken l.	1944	*+19.0*	+10.5	−5.7	−10.1	−3.1	−2.0	0.0	0.0	−1.4	+1.2	*+8.4*	+5.6
Zinfandel	1945§	−0.3	−1.8	−13.0	−3.0	+1.6	+7.6	+1.4	+2.9	+1.8	+5.7	0.0	−6.3
Napa County													
Beaulieu Vyds.													
Bale l													
Cabernet S	1945	−5.9	−10.3	−8.4	−6.2	+1.4	+0.8	−2.2	−1.4	−3.6	−2.2	+8.0	−8.0
Semillon	1945	+3.7	−3.7	—	—	+3.1	+0.4	—	—	−1.4	−1.4	—	—
Hummel	1943	+38.0	—	—	—	—	—	—	—	—	—	—	—
Butte s. l.	1944	*+65.0*	—	—	—	—	—	—	—	—	—	*+145.0*	—
Green Hungarian	—	*+72.5*	—	—	—	0.0	—	0.0	—	−3.4	—	*+113.0*	—
Grand noir	1941¶	+14.6	−0.5	−13.8	−3.4	+1.0	+2.0	−3.4	0.0	−0.8	−2.8	—	—
	1942	+16.8	+4.2	−5.7	−11.0	−2.1	−1.0	—	—	−2.1	+0.3	*+27.4*	*+18.6*
	1943	+13.0	+3.7	−19.7	−19.7	+2.1	+3.7	−7.9	−17.9	+4.4	+1.6	*+53.8*	+36.8
	1944	+36.0	−3.8	−26.4	−7.4	0.0	+1.5	−7.0	−14.0	+5.1	+1.5	*+63.5*	*+38.0*
	1945	+9.2	+36.5	−9.0	−8.0	−5.3	−2.3	+0.1	+1.1	+2.6	+1.1	*+40.0*	*+29.8*
Santa Clara County													
Mirassou	1944	−10.4	+16.5	+3.9	+1.0	−0.4	−1.2	−0.8	+3.4	−0.2	+1.9	*+10.8*	*+14.5*
Zamora c. l.	1945	−2.5	+9.4	−4.0	+2.0	−0.6	−0.3	+9.3	+6.2	+1.2	+5.0	—	—
Zinfandel													
San Joaquin County													
Jahant	1941	+14.9	+6.6	−22.0	−27.0	−2.6	−2.2	+5.1	+5.1	−1.4	−1.2	+2.0	+3.5
Madera l	—	—	—	*−25.7*	*−30.2*	*−3.6*	*−5.4*	*+7.7*	+5.3	*+3.4*	+1.4	—	—
Tokay													
Haabesland	1941¶	+24.0	+10.5	−29.4	−26.5	−3.1	−5.3	+4.3	+5.0	+3.4	+9.2	−7.7	−8.3
Hanford s. l.	1942	*+30.5*	+75.7	*−41.0*	*−32.0*	−10.0	−9.4	*+11.1*	+2.7	+1.7	+5.4	+13.6	+22.2
Tokay	—	+19.3‖	+22.4‖	−13.0	*−23.0*	−4.8	−7.8	+5.4	+8.2	−6.7	−9.9	—	—
	—	+3.7‖	−10.0‖	−5.3	−9.5	+1.1	+1.1	−1.6	+1.6	−3.1	−4.7	—	—

Skinner	1944	*+23.8*	*+15.4*	-11.9	-12.1	-0.6	-0.6	+5.9	+2.9	+1.9	+1.0	+23.8	+15.4
Hanford s. l.	1945	+8.6	+22.0	-21.0	-9.0	-2.1	-1.4	+8.0	+10.0	-2.1	+1.3	*+20.1*	*+9.2*
Tokay													
Woodworth	1944	+5.5	-5.0	-4.7	-7.9	-1.3	-1.3	+6.0	-2.4	+1.2	-0.5	+8.8	+0.5
Madera s. l.	1945	+8.5	+3.8	-16.0	-11.0	-3.4	-2.0	+6.4	+4.0	+1.1	+2.1	+5.3	+7.8
Tokay	——												
Stanislaus County													
Thompson	1942	+11.0	+1.2	—	—	*+2.4*	-0.4	*+2.7*	-0.2	+0.3	-0.1	—	—
Fresno s. l	1943	+15.8	+4.0	—	—	-2.9	-5.0	+5.0	+6.7	+3.5	-0.7	-3.6	+4.0
Sultanina	——	—	—	—	—	0.0	0.0	0.0	+3.3	-3.1	-5.0	—	—
Parrish	1942**	*+9.9*	+3.1	—	—	-1.3	-0.1	+1.4	-2.0	+1.3	-2.4	+14.4	+6.8
Oakley and Fresno s.	1943	+11.7	+1.7	—	—	0.0	-0.5	+2.7	+2.7	+3.2	+3.2	—	—
Sultanina													
Saunders	1942**	-2.2	-3.2	—	—	—	—	-0.4	+1.4	+0.9	-2.9	*+15.7*	*+9.0*
Fresno s. l.													
Sultanina													
Ewing	1945	+15.7	+9.3	—	—	—	—	—	—	—	—	+1.6	+10.7
Fresno s.l.													
Sultanina													
Lynch	1945	+11.5	+9.2	—	—	—	—	—	—	—	—	+9.3	+12.0
Fresno s. l.													
Sultanina													
Madera County													
Arakelian¶	1941	+4.4	+4.7	—	—	-1.7	-0.3	+0.9	-2.4	+1.1	+1.9	-3.0	+1.1
Oakley and Fresno s.	1942	—	—	—	—	-3.5	-3.0	+1.0	+3.1	-0.8	+1.2	—	—
Sultanina													
Ficklin	1943	-5.7	-2.5	—	—	-6.8	-2.3	+2.7	-1.4	0.0	-0.4	-1.1	-1.9
Madera s. l.	1944	+5.0	-0.4	—	—	—	—	—	—	—	—	+3.5	-3.0
Sultanina	1945	-3.8	-3.9	—	—	—	—	—	—	—	—	+5.7	-0.7
Fresno County													
Shattuck	1941	+16.6	+3.0	—	—	-1.9	-1.5	0.0	+3.6	-4.0	-4.5	+4.9	-1.0
Fresno s. l.	1942	*+28.3*	+15.4	—	—	*-5.1*	+3.9	+4.7	+0.9	-2.8	-6.9	+15.4	+10.5
Sultanina	1943	*+17.0*	+9.4	—	—	-1.1	+3.8	+1.4	+2.7	+3.0	+1.7	+10.2	+0.8
	——	+5.0	+19.0	—	—	—	—	—	—	—	—	—	—
Schlegel	1941	+5.4	+18.0	—	—	—	—	—	—	—	—	+6.7	+0.5
Fresno s. l	1942	+8.6	+6.3	—	—	+2.4	-2.2	+1.0	-0.7	—	—	+5.2	+1.4
Sultanina	1943	+2.6	-3.7	—	—	+1.5	+0.5	-3.6	-1.2	+3.7	+0.7	-0.9	+2.4
	——	-1.9	-8.9	—	—	—	—	—	—	—	—	+3.3	-2.5

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*s. =sandy, l. =loam, g. =gravelly, c =clay.

†Italized figures represent statistically significant differences by odds of 20.1 or more.

‡Results not significant because of bad mildew infestation and partial loss of yield records

§Results questionable due to red spider infestation.

¶Three replications.

||Approximated by product of number of clusters and average cluster weight.

**Frosted, results may be affected somewhat.

TABLE 1—*Continued*

Cooperator Soil Type* Variety	Years Fertilized	Yield		Color		Balling		Acid		Berry Size		Weight of Prunings	
		N	NPK	N	NPK	N	NPK	N	NPK	N	NPK	N	NPK
Tulare County													
George Madera s. l. Sultanina	1941¶	−4.6	+2.3	—	—	−3.1	−4.4	+6.6	+6.6	+1.3	+1.7	—	—
	1942	+25.6	+32.5	—	—	−1.6	−2.3	+5.2	+4.9	+4.1	−2.8	—	—
	1943	+18.0	+33.5	—	—	−2.6	0.0	+7.6	+4.5	+3.2	+0.7	—	—
Dobson Madera s. l. Emperor	1941	+9.1	+7.3	−7.0	+3.4	+0.4	−0.4	+3.8	+2.6	−1.8	−0.1	+0.1	+8.2
	1942	*−8.5*	*−7.1*	+3.8	+7.6	−0.3	−0.7	+5.8	+3.8	−4.1	−3.0	+2.9	+3.4
	1943	−5.3	−9.3	−3.3	+3.3	−3.7	−1.9	+6.0	+6.0	−4.8	−9.8	+0.9	−1.1
				−3.8	+5.2	−0.6	+0.6	−2.0	0.0	+0.4	+0.2	—	—
Kern County													
Caratan Hanford s. l. Sultanina	1941	+6.9	+2.1	—	—	−3.0	−0.3	+4.9	+3.9	+6.1	0.0	+3.7	+0.5
	1942	−3.9	−0.3	—	—	+2.5	0.0	−4.7	−0.5	−0.5	0.0	+1.1	+0.9
	1943	+4.9	−2.2	—	—	−0.5	+1.5	+2.9	+1.5	−0.9	−0.3	−3.4	+2.6
		−0.3	+0.5	—	—	—	—	—	—	—	—	−12.7	−5.6
Jenans Hanford s. l. Malaga	1941	+2.5	−6.0	—	—	−0.4	−1.3	+9.9	+11.4	−4.3	+2.2	−2.5	+7.2
	1942	−5.1	−3.4	—	—	*−7.9*	−4.3	*+19.5*	*+15.8*	*−10.2*	−5.6	−6.3	−10.4
	1943	*+53.2*	*+34.9*	—	—	+9.7	+11.0	+5.4	+8.9	−8.4	−2.4	+11.6	+13.9
		+0.5	−13.4	—	—	—	—	—	—	—	—	+0.2	+14.0
	1945	*+19.0*	−5.7	—	—	—	—	—	—	—	—	−7.7	−6.1
Weller Hanford s. l. Molinera	1941	+6.2	+6.8	+4.7	−0.6	—	—	−0.5	+3.5	−0.8	+0.6	+8.4	+6.8
	1942	+1.1	+31.5	−5.0	−3.0	−0.8	−1.3	−1.0	+4.6	+6.3	−0.5	−5.8	−4.2
	1943	*+4.1*	*−7.1*	−2.1	+5.2	0.0	+2.3	+6.3	+6.3	−0.1	−1.6	+10.0	+10.4
Ribier	1941	—	—	+17.5	+12.5	−1.0	−2.5	+1.8	+4.6	−0.5	+1.3	−3.9	−4.1
	1942	*−16.3*	*−15.3*	+11.7	+22.8	−3.2	0.0	+11.8	+7.2	−4.6	−2.8	−0.9	+7.2
	1943	−1.9	−10.9	0.0	+25.0	+0.2	+0.6	+1.5	+1.5	+1.0	+2.7	+3.4	−7.7
		−2.5	−10.8	—	—	—	—	—	—	—	—	—	—
Walker Hanford s. Ribier	1941	+9.0	+2.6	−19.2	−15.3	−6.8	−3.3	+17.5	+8.3	—	—	+5.0	+8.2
	1942	—	—	−14.5	−11.6	−4.7	−7.8	*+11.1*	*+11.2*	+3.1	+5.1	*+36.0*	+34.7
	1943	+14.0	−5.5	0.0	+10.7	−3.4	+0.6	*+15.0*	*+10.0*	+1.1	+7.0	+33.2	+32.4
	1944	+13.6	+13.7	−6.0	−0.3	+4.3	+6.1	+14.1	+9.1	−3.5	−1.7	*+36.0*	+15.6
	1945	+7.9	+5.2	−7.0	+16.3	−5.3	−3.5	+5.1	+1.4	−7.1	−4.4	+4.5	+0.2

*s. = sandy, l. = loam, g. = gravelly, c. = clay.

†Italized figures represent statistically significant differences by odds of 20:1 or more.

‡Results not significant because of bad mildew infestation and partial loss of yield records.

§Results questionable due to red spider infestation.

¶Three replications.

||Approximated by product of number of clusters and average cluster weight.

**Frosted, results may be affected somewhat.

three replications, and under the conditions prevailing, such plots were not sufficient for conclusive results. Odd figures appear at times, such as the +75.7 per cent increase for Haabesland's Tokay NPK plot. This is also one of the plots having only three replications, and one of the NPK replications had an excessively high yield, possibly through an error in picking records. Similarly, the +31.5 per cent occurring in Weller's Molinera plot for 1942 probably is accidental. In no case has a statistically significant increase been apparent in the various fertilizer plots when the NPK treatments were compared with the corresponding N lots.

Walters (9) in fertilizer trials in Australian vineyards, found most often a 10 per cent yield increase from N and no response from P or K applications. He did not find a crop increase until the second year of application, so he believed the additional yield resulted from increased bud fertility and vegetative vigor. The results presented in Table I, however, indicate a yield response commonly occurred in the first year, although an increased effect appeared in the following years. In 1941 the plots initiated by furrow application seemed to have had little increased growth (pruning weights); however, the subsequent new plots frequently have shown increased growth. The difference is possibly due to an earlier availability of the material which has been machine-placed in the soil in the later plots. Some such differential response, perhaps brought about by variation in application procedure, may account for Walter's failure to find yield increases the first year.

From analogy to annual crops the assertion is commonly made that there is danger of disastrous results following fertilizer application to dry-land vineyards. The greatest percentage increase in yields and growth in this study have occurred in the unirrigated vineyards (cf. Salinger and Hummel data).

In three plots (Dobson's Emperor for 1942 and Weller's Molinera in 1943 and Ribier in 1942) the fertilized lots yielded consistently less than the surrounding checks. The odds are better than 100 to 1 that the decreased crop resulted from both N and NPK applications in two of these cases. The magnitude of the effect seems to be about the same for both N and NPK treatments, which would seem to point to a nitrogen effect, rather than any possibility that the 3½ pounds of NPK fertilizer per vine had accentuated a high salt condition. The vineyards were making good growth in all three cases. Overly vigorous growth with straw mulch and with fertilization presumably produced decreased fruitfulness (10, 11) in Concord grapes, but practically there is no indication of such an increased vigor in the cases cited above (see pruning weights from these plots). It seems most likely that the nitrogen has accentuated some imminent deficiency, possibly indirectly. Weaver, Jean, and Crist (12) find that where roots came in contact with a fertilized layer they branched profusely, and their further penetration was retarded. Such a phenomena would, of course, tend to limit further the absorption of a deficient element. Such findings as those of Gourley (13) in Ohio wherein manure seemed to be more effective than mineral fertilizers may be related phenomena, particularly in view of the more common findings on other crops that manure is not as effective as an amount of commercial fertilizer of equal NPK content.

Color development is very important to the growers of such table grapes as the Emperor and Tokay. Most of the color figures in Table I indicate that nitrogen ordinarily decreases color. This is particularly evident in the Tokay vineyards in San Joaquin County. In 1945, 60 per cent more of the grapes from the N test plots in the Woodworth vineyard were sent to the winery as culls than were rejected for table-grape use from the check lots. A general application of this much nitrogen (327 pounds of ammonium sulfate) in successive years would have resulted in considerable financial loss.

Only in Weller's Ribier plot has the nitrogen seemed to increase color development, which in this instance was probably connected to the decreased crop. It is noticeable that the N had relatively little effect in the other two plots (Dobson's Emperor and Weller's Molinera plots) wherein the yields seemed to have been decreased notably. The markedly increased yield from Salinger's Carignane plot has not been accompanied by a color decrease. Quite possibly a marked nitrogen deficiency may be corrected without color impairment, although the Carignane result may have arisen from a varietal characteristic. Webster and Cross (14) found that N fertilizer increased Concord grape color slightly.

A comparison of the relative color decrease for the Tokay vineyards shows a —23.1 per cent for N and —21 2 per cent for NPK treatment. It seems that the results from P and K additions have not supported the hopeful statement appearing in a recent textbook that phosphorus hastens maturity, strengthens root development, increases disease resistance, encourages flowering and fruiting, hence powerfully counteracting any possible detrimental effects of excess nitrogen. At any rate, the addition of P and K to the N treatment has not noticeably counteracted the color decrease resulting from the N application.

It appears from the 1941 results of the Jahant and Haabesland plots that color may be markedly decreased without an appreciable increase in pruning weights. This data would indicate that the shading influence is probably at least secondary. Possibly a nitrogen excess may have a direct influence upon color development, particularly since the effect on the sugar and acid content of the grapes has been relatively small.

Gladwin (15), van Haarlam and Upshall (16) have found that fertilization did not appreciably influence the sugar content of the grapes. In this investigation, however, the Balling degree (approximate sugar content) data, as well as the acid content of the juice, indicate a fairly consistent but slight delay in ripening. The average differences for all the plots indicate a decrease in the sugar content of —1.6 per cent for N and —1.0 per cent for NPK. An increase in acidity of +4.0 per cent for N and + 3.3 per cent for NPK treatment occurred. These differences are all statistically significant; however, they represent only 1 to 3 days' delay in maturity, hence are not of practical importance. In a few instances (notably Jenan's Malaga and

Walker's Ribier plots), a marked increased in acidity has occurred. There seems to be no evident reason for this abnormality.

The berry-size fluctuation is small. Neither N nor NPK has had an appreciable influence. The averages are —0.3 and —0.6 per cent respectively for N and NPK.

The pruning weights seem to correlate fairly closely with yield results. The over-all average of +10.5 per cent for N and +8.1 per cent for NPK stands very close to the relative yields—that is, 9.9 per cent and 7.2 per cent respectively. The odds are more than 100: 1 that the differences are significant. Inspection of the data suggests that the pruning weights serve to check the yield records. Such a check is particularly desirable, since the distance involved and the multiple pickings of table-grape vineyards have rendered it impractical to supervise personally the harvesting, especially since the grapes are commonly picked on very short notice.

The pruning weights are of further value, as they may indicate incorrect pruning practices; that is, if additional growth is obtained without commensurate crop increase, longer pruning is advisable in order to utilize the growth in fruit production if possible.

Summary and Conclusions

California vineyards have shown on the average about a 10 per cent yield increase resulting from N application. The addition of P and K have tended to depress the effect of N and, in no case have statistically significant yield increases resulted from the addition of P and K in the present experiments.

Nitrogen has a marked deleterious effect on the color development of Tokay grapes, which decidedly limits the amount of nitrogen which can be used if these grapes are to be sold for table use. The addition of P and K to the nitrogen has had no appreciable effect in overcoming the diminution of color brought about by nitrogen.

The sugar content was lowered slightly, and the acidity was increased slightly and to about the same extent by either N or NPK fertilization.

The pruning-weight changes largely correlate with the yield changes and serve as checks on harvest records as well as to indicate incorrect pruning practices.

The berry size does not seem to be appreciably influenced by the fertilizer applied.

It appears that on the average moderate nitrogen applications will at least pay the cost of the fertilization and in many instances will be quite profitable. Phosphate and potash applications added to the nitrogen, on the other hand, seem to be slightly detrimental.

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The Propagation of Coffee *(Coffea arabica* L.) by Cuttings

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THE vegetative propagation of coffee by cuttings has been tried in several coffee regions (2, 8, 13, 20, 25) as a means of propagating desirable highly-productive or disease-resistant strains. Results have been discouraging and uncertain in many instances since only fair percentages of rooting have been obtained with elaborate, and often costly methods (19, 10, 17, 9). High percentages have been observed only through the use of terminal shoots from very young plants (25). This method is of little value because such types of woods are obtainable only from plants not yet tested for productivity or other desirable characters.

The present paper summarizes experiments made in Puerto Rico by the author and other workers, and shows that satisfactory results may be obtained, using wood from bushes old enough to have shown their merits.

LITERATURE REVIEW

A review of considerable literature on the propagation of coffee by cuttings, and a study of numerous articles published on similar types of propagation for other plants, bring overwhelming proof of the statement made by Knight and Witt (18). Summarizing their experiments on the vegetative propagation of plants by cuttings, they state "Not only is it necessary to use different propagation methods for different species and genera, but even varieties closely similar frequently respond quite differently to the same treatment. Consequently, the propagation problem resolves itself at first into a series of empirical trials of every variety which may be required. Elucidation of the principles involved is of considerable value in a general way, but application of these principles to each individual variety is handicapped by this wide variation of inherent potentialities".

The following review of the work done on the vegetative propagation of coffee in the past twenty years clearly substantiates the above generalization.

It is reported from Kenya (2) and Uganda (8) that large woody cuttings 2 feet long x 1½ inches in diameter, (which are readily obtained after prunings) root easily. No percentages are given, and from observations made in Puerto Rico by the writer using such material,

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external growth may be misleading. Cuttings of this size often produce abundant foliage and remain alive for over six months, giving the impression that rooting has taken place; yet, upon examination, roots are entirely absent.

Soft-wooded leafy cuttings are generally found to be the best type of wood to use according to Tanganyika (3), Guiscafré-Arrillaga (13, 15), Gómez (16), and van Overbeek *et al* (24, 25). In this connection van Overbeek *et al* report that not only soft-wooded cuttings (especially shoot terminals) must be used, but also that a 100 per cent rooting is obtained only when using young one-year-old plants. They also reported a steady decline in rooting with increase in age of plants regardless of auxin treatments to hasten rooting. This is in accord with the observations of Thimann (22) who, working with difficult-to-root species of other plants, found that "the ease with which roots are formed in one-year-old wood falls off with increasing age of the tree whether the cutting is treated with growth substances or not". Cheeseman (4) had similar results with cacao, getting a higher percentage of rooting when using cuttings from leafy, young wood of trees of non-bearing age. Guiscafré-Arrillaga (14) and Jackson (17) reported some success with non-leafy, mature-wood cuttings. In the former instance, success once attained using this type of wood was never recorded again, even after repeated trials.

The application of hormones has been found to be of importance in inducing rooting by Guiscafré-Arrillaga and Gómez (13, 14, 15), Gómez (16), Coffee Research Station, Tanganyika (20), and van Overbeek *et al* (25). However, evidence from van Overbeek's studies and data to be reported in this paper, point out clearly that auxins function in the rooting of coffee cuttings by increasing the number of roots and by shortening the time ordinarily taken by cuttings to root. Other factors such as the presence of leaves and the provision of adequate temperature and moisture are more important. The important role played by leaves in the rooting of cuttings have been definitely demonstrated by Gregory and van Overbeek (11) and van Overbeek, *et al* (26, 27).

Hormones applied in solution have been found by some workers to be more efficient than when applied in dust mixtures or lanolin pastes, Gillet and Jackson (10), and van Overbeek *et al* (24, 25). On the other hand, dust mixtures and lanolin pastes have been found to be more effective by others, Guiscafré-Arrillaga and Gómez (13, 14, 15, 16) and Roelofsen (21). Roelofsen (21), from Java, reports hormones to be harmful and useless when in solution, and, although not a completely efficient substitute for removed tops, a lanolin and hormone mixture was more successful in inducing rooting when compared to topped, nontreated cuttings.

Rooting has also been induced to some extent in coffee through the use of more complicated methods. Gillet and Jackson (10) obtained higher rooting percentages by allowing the hormone solutions to penetrate the basal part of cuttings in vacuo. Jackson (17) also obtained a higher percentage of rooting of coffee cuttings by exposure to yellow light, but found red and blue light to be ineffective. Gillet (9) and

Jackson (17) induced rooting when using etiolated ring-barked suckers through earth mounding.

McClelland (19), reported complete failure of coffee cuttings to root after repeated trials with wood of all ages. He got 50 per cent rooting by air layering (chinese layering method of propagation), which is a slow process and represents quite a loss of propagating material.

METHODS

Considerable time was spent in the endeavor to force coffee cuttings to root, testing all methods tried on coffee and other plants elsewhere, using some of the complicated methods outlined in the literature review, trying cuttings of various sizes and ages, planting through all seasons of the year, testing synthetic hormones in powder form or in solution, and planting in especially designed propagators with and without bottom heat and with provisions to protect the cuttings from direct sunlight and to maintain adequate moisture. It was not, however, until the last two years, when it was possible to use the type of propagator designed by the Imperial College of Tropical Agriculture of Trinidad, British West Indies, that leads were obtained on the right type of wood to use, and observations were made on the beneficial effect of keeping leaves or parts of leaves attached to the cuttings. After numerous trials it was also found that more success was obtained with a two-type-wood cutting than with any other. The two-type-wood cutting has a green top but a well-matured base of brown color. Propagating material of this kind is easily obtained by bending vertical shoots and keeping them in a horizontal position, pegged to the ground. Once the terminal bud is changed from the vertical to the horizontal position, a profuse sucker growth is initiated which produces excellent material of the two-type-wood after four to six months (Fig. 8).

RESULTS

When almost complete failure resulted after so many trials, it was thought that the poor rooting response of coffee cuttings was due possibly to the absence of tissues capable of forming roots. A simple test was performed to find out whether this was true. Six plants approximately 3 years old (4 feet tall) were almost buried in a vertical position in a trench 3 feet deep. The trench was filled with good soil and the tops watered frequently. When these plants were dug up and examined three months later, roots had formed along the buried stems, Fig. 1; also Guiscafré-Arrillaga and Gómez (12). They showed definitely that under special conditions the coffee plant produces adventitious roots, without applying drastic treatments such as ring barking, wounding, bending the stems (layering), and so on.

Wound or adventitious roots had been obtained by other workers, Gillet (9), Jackson (17), and McClelland (19). It may be concluded, therefore, that the coffee stem has the ability to form roots when properly treated or under special conditions.

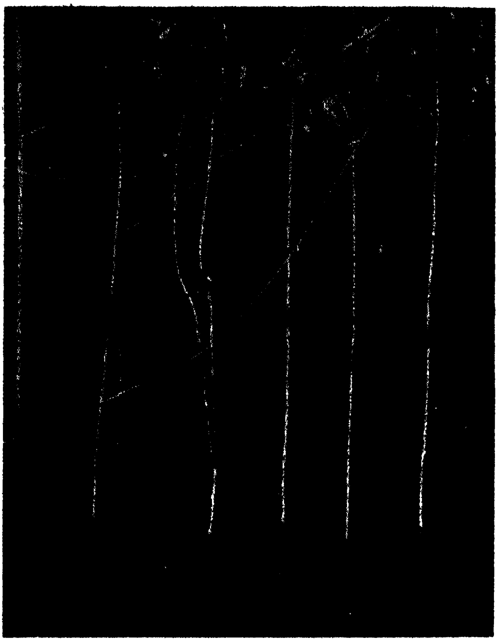

FIG. 1. Coffee plants over 2 years old, showing roots formed along the stems buried in trenches 3 feet deep.

When using leafless cuttings it was observed there was a tendency in those surviving for a few months to develop leafy shoots but no roots. Apparently, reserves were exhausted in the effort of the cuttings to form leaves, leaving little or none of the vital substances for inducing rooting.

Leafy shoots planted under special propagators also failed to root and finally decayed. This was later found to be due to lack of proper moisture and temperate conditions.

The I. C. T. A. type of propagator, fully described by van Overbeek *et al* (24) is almost ideally suited for the propagation of plants by leafy cuttings in the tropics.

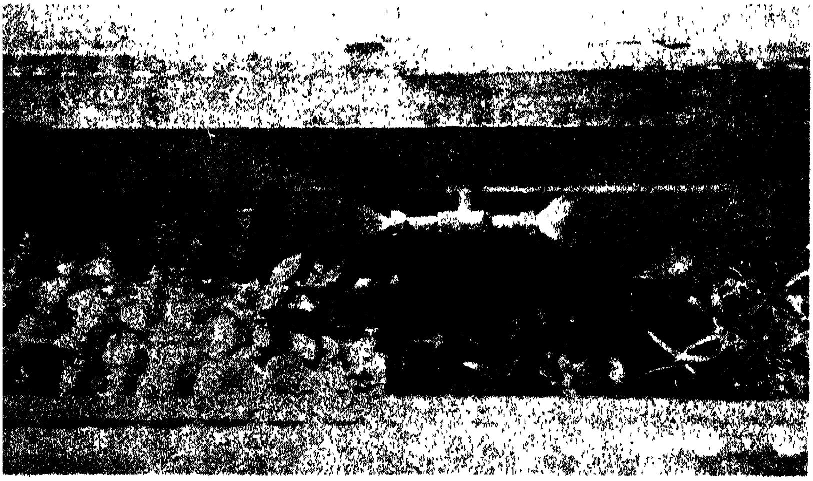

FIG. 2. Propagator of the type developed by the Imperial College of Tropical Agriculture, Trinidad, British West Indies, with spray nozzles to provide a "mist" over the cuttings for a desired length of time.

It was found, however, that results were unpredictable because of the variable moisture supply. Elsewhere moisture is supplied daily by spraying water with a hose at different intervals. It must be realized that little control of the quantity of water applied is obtained in this way. To avoid this drawback, ordinary sprayer nozzles were installed inside the propagator (Fig. 2) to supply water in the form of a mist between 9:00 a. m. and 3:00 p. m. daily. Continuous records obtained by a hygrothermograph placed in the propagator recorded an average

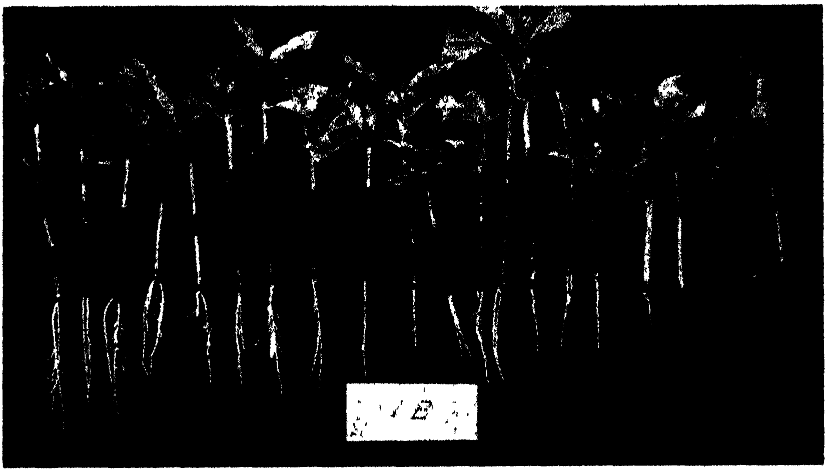

FIG. 3. Rooting obtained with 5-months-old wood planted in the propagator in plain sand.

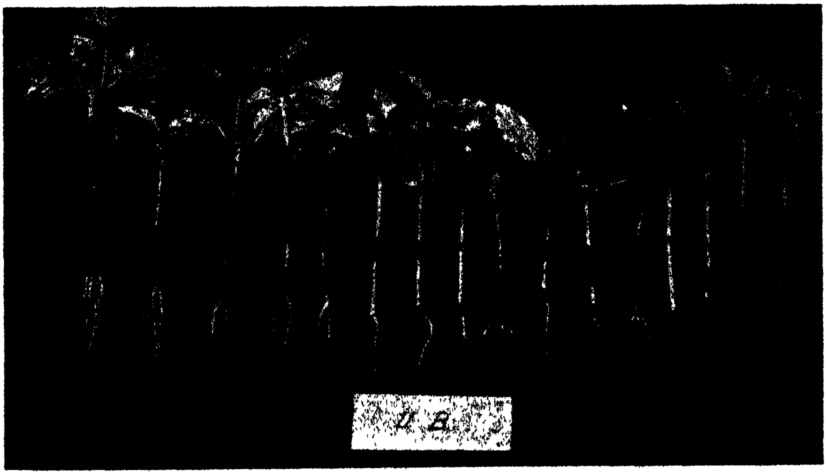

FIG. 4. Rooting obtained with 5-months-old wood treated with 4 mg/cc of indolebutyric acid in 50 per cent alcohol for 5 seconds and planted in plain sand in the propagator.

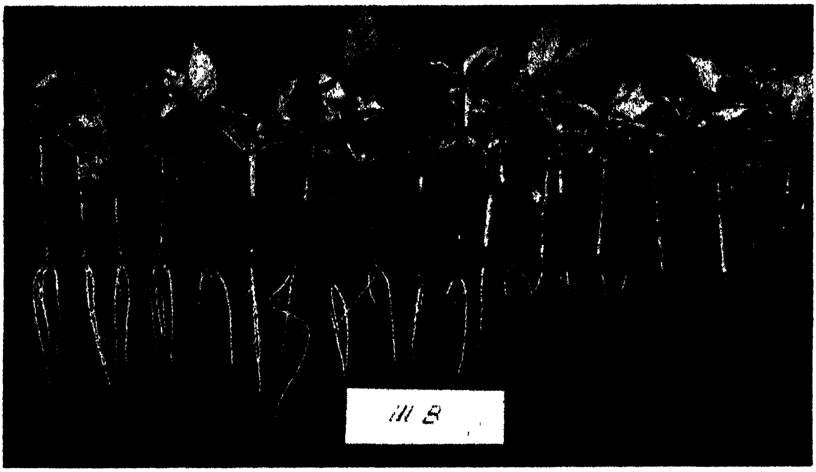

FIG. 5. Rooting obtained with 5-months-old wood treated with Hormodin No. 3 and planted in plain sand in the propagator.

daily temperature of 76 degrees F and a relative moisture of 86 per cent. A continuous drip over the glass cover of the propagator and a lath frame admitting 50 per cent sunlight also help to keep daily temperatures low and relative humidity high, with neglible fluctuations.

As a result of numerous tests, it was found that one type of cutting was decidedly superior to all others, rooting consistently through all seasons of the year. This type is that obtained from sucker growth four to six months old, the bases of which are of brown wood of intermediate maturity between succulent and hardwood. The tops of these cuttings are soft wooded. In order to obtain 2- or 3-node cuttings 5 to 8 inches long, the succulent tops were pruned, leaving two full leaves if these were small. If large leaves were present, half of each leaf was cut to reduce transpiration. Some rooted cuttings of these trials are shown in Figs. 6 and 7.

No apparent relations were ever found between rooting and size of cutting, or position and shape of the cut.

Such precautions as wrapping immediately in a wet burlap after removing from trees, making a new cut previous to planting, and planting as soon as possible after removal from the field were always found highly beneficial in reducing wilting and premature decay. Making a second cut under water previous to planting was tried several times without apparent results.

In Table I, results of some treatments are given. All cuttings had bases of semi-hardwood and soft-wood tops. It is observed from these tables that Hormodin, although not appreciably affecting the percentage of rooting, increased the quantity of roots. Observations before the final pulling date showed that hormodin-treated cuttings started to root earlier. These observations are comparable to those of van Overbeek (24).

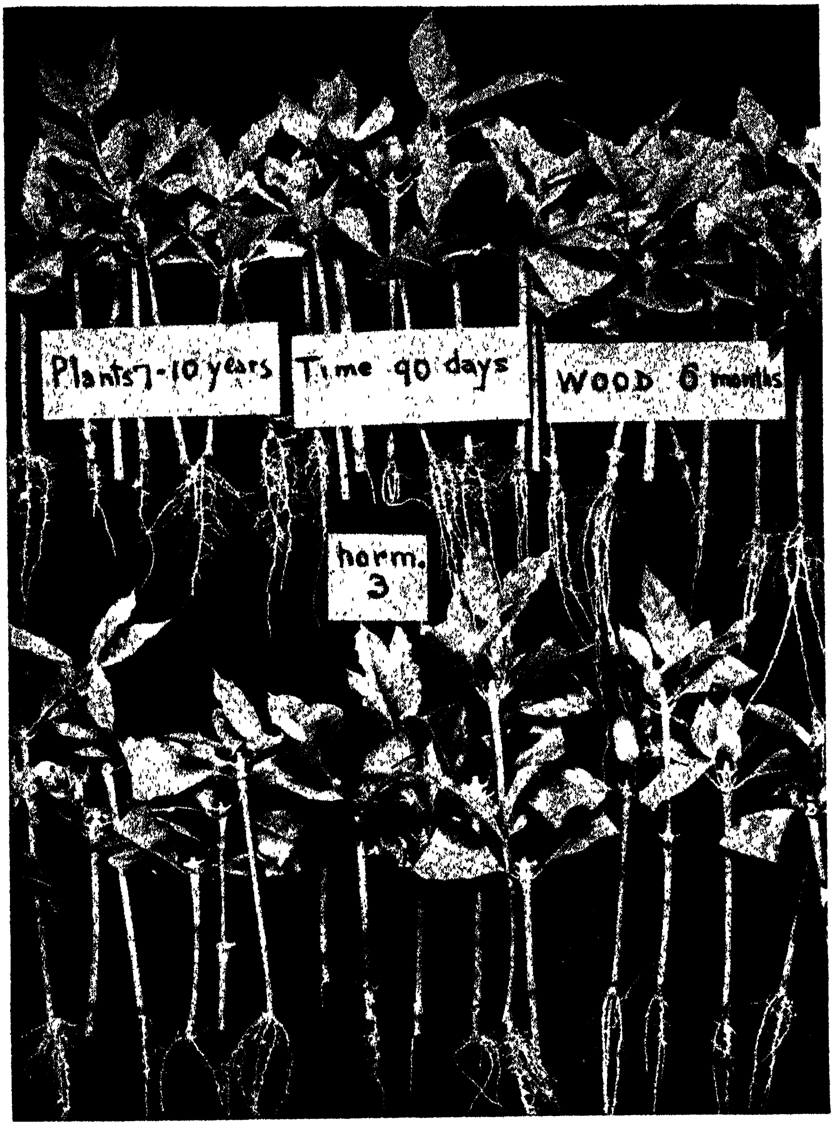

FIG. 6. Rooting obtained in 90 days of 6-months-old wood from fully matured coffee plants. Bases treated with Hormodin No. 3.

In this test, the concentration of indolebutyric acid used may have been too high. Again "no treatment" is comparable to the application of Hormodin No. 3, but, as shown in Figs. 3, 4, and 5, root systems were more profuse in cuttings treated with hormones.

In this test over 90 per cent rooting was obtained when including the number of cuttings callused. These invariably root if left 30 days longer.

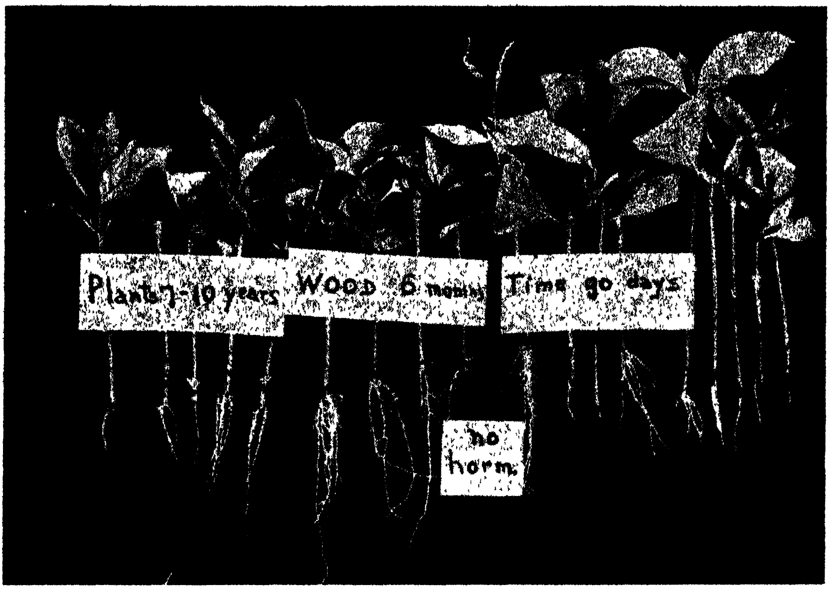

FIG. 7. Rooting obtained in 90 days of 6-months-old wood from fully matured coffee plants. No special treatment applied.

TABLE I—RESULTS OF SEVERAL TRIALS IN ROOTING OF CUTTINGS

Type of Wood	No. Cuttings	Treatment	No Rooted	Rooting Per Cent	Time (Days)
		Planted April 6, 1945			
Leafy terminals	40	Plain beach sand, in propagator	10	25	103
Leafy, base semihard	40	Plain beach sand, in propagator	32	80	103

Treatments	No. Cuttings	Type	No. Rooted	Rooting Per Cent	Time (Days)
		Planted November 30, 1945			
Equal parts of "cachaza"* and sand +hormodin No. 3	52	Softwooded top with semi-hard base leafy	26;11 callused	50	90
Same medium, no hormodin	52	Softwooded top with semi-hard base leafy	25;10 callused	48	90
1 part "cachaza" 3 parts sand + hormodin No. 3	52	Softwooded top with semi-hard base leafy	33,13 callused	65	90
Same medium, no hormodin	52	Softwooded top with semi-hard base leafy	28;17 callused	55	90
		Planted March 21, 1946—Sand Medium			
I B—No treatment	25	Softwooded tops semi-hard bases, leafy	18:4 callused	72	120
II B—4mg/ml in 50 per cent alcohol indolebutyric acid, 5 seconds	25	Softwooded tops semi-hard bases, leafy	12,4 callused	48	120
III B—Hormodin No. 3	25	Softwooded tops semi-hard bases, leafy	17:6 callused	68	120

*"Cachaza" is the filter-press-cake from sugar cane mills.

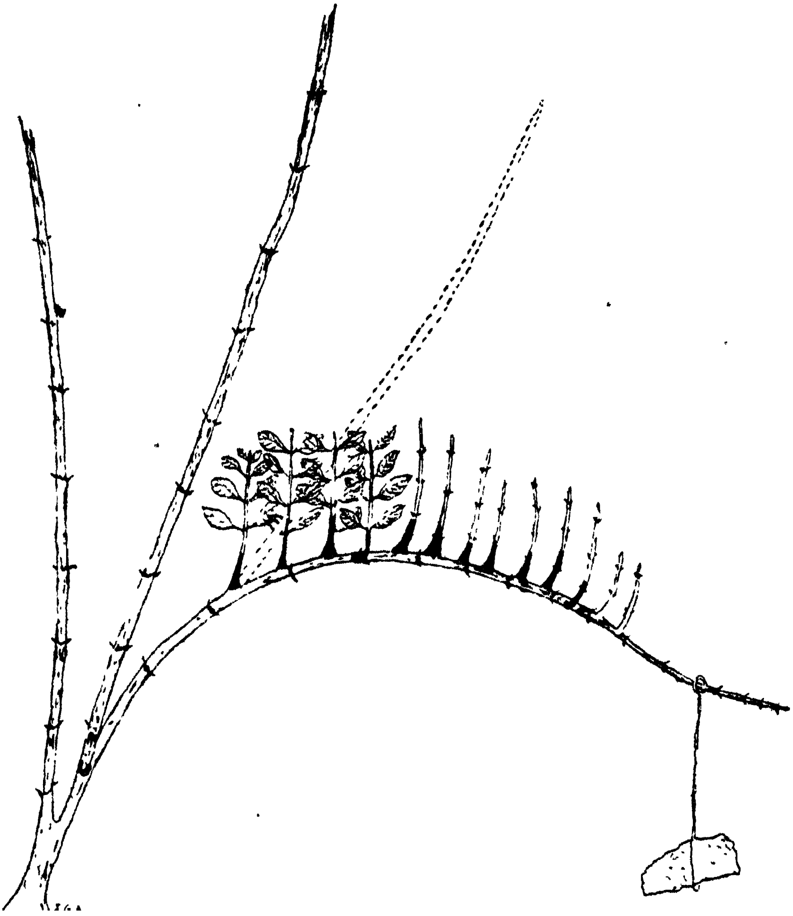

FIG. 8. Bending of vertical branches stimulates the growth of numerous suckers which when 6 months old provide excellent material for cuttings with bases of semi-mature (brown) wood and tops of soft (green) wood. In this sketch the black color represents brown wood and white represents green wood.

DISCUSSION

The present paper discusses the efforts and degree of success attained in the vegetative propagation of coffee from cuttings by workers in Puerto Rico and elsewhere.

High rooting percentages have been obtained by attention to three important factors, that is (a) the specific type of wood used, (b) the adequate environmental conditions provided by the propagator developed in Trinidad at the Imperial College of Tropical Agriculture, and (c) the role played by leaves.

It was realized after many failures that leafy cuttings were necessary. Efforts to provide conditions which would make the leaves remain attached to the cuttings failed completely until an I. C. T. A. type of propagator was used. The extremely important effect of the leaves on the rooting of cuttings have been demonstrated through the experiments of van Overbeek and Gregory (26), Gregory and van Overbeek (11), and van Ovebeek, Gordon, and Gregory (27). Leaves have a nutritional effect supplying the cuttings with the necessary sugars, amino acids and other substances, necessary for rooting.

The artificial application of hormones has been shown to accelerate rooting and to produce more extensive root systems, van Overbeek *et al* (24), but not to be indispensable for the rooting of coffee cuttings. Wherever leaves are left attached, and conditions prevail so as to keep them healthy, rooting takes place normally in the absence of externally applied hormones. Apparently the quantity of auxin needed for rooting is supplied by the cuttings.

High percentages of rooting have been obtained using two different types of wood. van Overbeek *et al* (25) obtained 100 per cent rooting with terminal shoots of one-year-old seedlings. The writer obtained over 75 per cent rooting, using cuttings with semi-hardwooded bases and soft wooded tops of fully matured trees. Still a greater percentage (over 88 per cent) may be expected if cuttings are left more than 120 days in the propagator. The advantages in using this type of wood are obvious. Plants tested for desirable characteristics can be propagated, and the propagation material is easier to obtain and more abundant.

Once rooted, the cuttings may be potted. Using a soil mixture of one part of the same kind as the rooting medium and one part of silt, and kept under adequate shade, these develop readily and generally attain a larger size than seedlings of similar age. Cramer (5) also reports success after rooting has taken place if cuttings are properly handled. Gillet (9) has studied the root systems of plants raised from cuttings and found them satisfactory and comparable to seedlings of similar age.

As a final word, the importance of maintaining specific levels of moisture and temperature cannot be overemphasized. Excess of moisture induces premature decay, and too high temperature causes wilting and defoliation.

SUMMARY

1. The literature on the propagation of coffee by cuttings has been reviewed. Additional information concerning the propagation of coffee and other tropical plants by cuttings may be obtained by consulting Fielden (6) and Garner (7).

2. Rooting of coffee cuttings has been obtained in high percentages (above 75 per cent, using a two-type-wood cutting, that is bases of the semi-hard brown wood and tops green but hard. The cuttings should have two leaves or portions of leaves attached at the uppermost node. Over 88 per cent rooting may be expected if cuttings are left more than 120 days in the propagator.

3. Specific moisture and temperature levels must prevail during rooting to prevent wilting, defoliation, and premature decay. Such

conditions are readily obtained by the use of the I. C. T. A. (Trinidad) type of propagator covered with a lath frame to admit 50 per cent sunlight and with spray nozzles installed inside to supply minimum but continuous amounts of water during the critical time of the day (from 9:00 a. m. to 3:00 p. m.).

4. The artificial application of hormones accelerates rooting and increases the quantities of roots developed but does not necessarily induce rooting.

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Correlations Between Seed and Berry Development in Some Seeded Varieties of *Vitis vinifera*

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It is common knowledge that seed development in the grape has a very pronounced influence upon the growth and ultimate size of the berry. This effect is strikingly shown in certain varieties such as the Hunisa, which often produces two types of berry on the same cluster, one being small and parthenocarpic and the other large and seeded(5). Excellent examples are afforded by the somatic mutations described in the literature in which varieties regularly producing a certain grade of seedless fruit have changed back to a seeded form of much larger berry size (1). Mutations involving a uniform reduction in seed development have also been described; the most interesting case of this sort is the origin of a seedless variety from the seeded Emperor (4).

The breeding of new varieties of seedless grapes requires that a female parent must be chosen that produces some viable seed, since the seedless variety is used as the pollen parent. A better understanding of seed and berry development and the possible variation to be met with among seeded varieties may result in a more intelligent selection of those most apt to transmit characteristics resulting in the uniform and early abortion of the developing ovules, and yet obtain seedless berries of large size.

The present report includes comparisons among six seeded *vinifera* varieties as to (a) correlations between seed weight vs. berry weight, and seed number vs. berry weight, (b) the frequency and types of seed found in the mature berries, and (c) the tendency toward parthenocarpic fruit development. A working hypothesis is then presented as a means of selecting seeded varieties that might best serve as parents in the breeding of new seedless varieties with large berry size.

In obtaining the fruit samples for analysis, twenty clusters typical of each variety were harvested. The fruit was mature and well colored at the time of sampling, but none of the berries were overripe or shriveled. Random portions of each cluster containing from 15 to 20 berries were then taken, until a total of 336 berries were obtained. Each berry was cut from the pedicel with a razor blade and weighed to the nearest tenth of a gram, then replaced in a small compartmented box. The seeds from each berry were removed by hand, counted, wiped clean on a damp cloth, and then replaced in the compartment previously occupied by the berry. The seeds coming from each berry were dried at room temperature for 48 hours and then weighed to the nearest milligram. A small control series of seeds of each variety weighed immediately after extraction was used to obtain the percentage of moisture loss, and the weights of dry seeds were recalculated on the wet basis.

Although all of the varieties are classified as seeded, *i.e.*, the large majority of berries contain one or more well-developed seeds of hard, flinty texture; they were chosen because of the typical varietal differences in berry shape and the range in berry size within the variety. The Burgrave produces ovoid-elongated seeded berries of very large size (8.007 ± 0.02 grams), but is also characterized by the regular production of a large number of "seedless" berries intermingled in the cluster. The curve representing berry weight is distinctly bimodal. The Dattier and Olivette blanche also produce elongated fruits, but casual observation over a series of years indicated that the production of "seedless" berries is less frequent than in the Burgrave. The Molinera (Red Malaga) approximates a spherical shape, and is characterized by very loose fruit clusters. The Muscat of Alexandria has short obovoid berries and is particularly interesting because of the unusually high viability of the hard seeds (3). The Ribier (Alphonse Lavallée) is characterized by very large spherical berries, with some flattening or depression of the stylar end. The six varieties chosen represent a fair cross section, although admittedly small, of the large-berried vinifera varieties in commercial culture.

In calculating the correlation coefficients between seed weight and berry weight all of the berries of the sample were used, those developing only small, soft seeds [stenospermic seeds according to Stout (6)], as well as the seeded berries having one or more hard seeds. Reference to Table I shows that the Muscat of Alexandria showed the high correlation of 0.931, the lowest correlations being present in the Olivette blanche and Ribier. All of the correlations are high, regardless of the differences in mean berry size and shape. The correlations between seed number and berry weight were calculated by classifying the berries as having 0 ("seedless"), 1, 2, 3, 4, etc., hard seeds per berry and do not take into account the presence of soft seeds occasionally developing in the same berry along with the hard seeds, although their weight is only a small fraction of the total seed weight of the berry. The uniformly high correlations obtained in all comparisons involving both seed weight and seed number leads one to expect that the weight of the berry and hence its size is largely determined by the relative development of the seeds and their number in the berry. It seems logical to suppose that new seedless varieties with large berry size will be most easily obtained if the aim is to produce a variety in which a large number of ovules per ovary are fertilized and undergo development to produce seeds, and that these seeds cease growth at a point just short of their being large and hard enough to be objectionable in the mastication of the fruit. This would, from the

TABLE I—CORRELATIONS BETWEEN SEED WEIGHT VS. BERRY WEIGHT AND SEED NUMBER VS. BERRY WEIGHT, IN SEVERAL VARIETIES OF *V. vinifera*

Variety	Seed Weight and Berry Weight	Seed Number and Berry Weight
Burgrave	0.830 ±0.017*	0.822 ±0.018
Dattier	0.827 ±0.017	0.804 ±0.019
Molinera	0.814 ±0.018	0.831 ±0.017
Muscat of Alexandria	0.931 ±0.007	0.900 ±0.011
Olivette blanche	0.780 ±0.021	0.741 ±0.025
Ribier	0.784 ±0.021	0.932 ±0.007

*Standard error.

standpoint of seed development, produce the largest sized "seedless" fruit. Such a type of seedless grape is well exemplified in the Sultanina (Thompson seedless), the most extensively cultivated of any of the "seedless" varieties. This quest would appear more promising than the attempt to breed for vegetatively parthenocarpic varieties that would be of smaller berry size because of the absence of the great stimulative effect of fertilization and the initiation of seed development.

In the six seeded varieties studied, the berries may be divided into two classes according to the degree of seed development. Those having one or more large, hard, and flinty seeds are *seeded.* Such seeds cannot be crushed with pressure of the finger tip. The second class of berries corresponds to the stenospermocarpic class of Stout (6), in which no hard seeds are present. These berries are commonly called "seedless" and are so referred to in this paper, yet they contain one or more rudimentary or partially-developed seeds, characterized by soft or brittle seed coats, which crush easily under the pressure of the finger tip. Obviously a more accurate definition of the word "seedless" as applied to grape varieties would seem desirable.

The number of hard seeds per berry is plotted in Fig. 1. It will be noted that the seed distribution approaches a normal curve in the Muscat and Ribier, whereas the curve in the case of the Burgrave and Dattier is distinctly skewed, the Molinera and Olivette being intermediate. The two varieties with lowest seed number per berry also have a greater tendency to form a large percentage of "seedless" fruits. Although the Olivette and Molinera show considerable re-

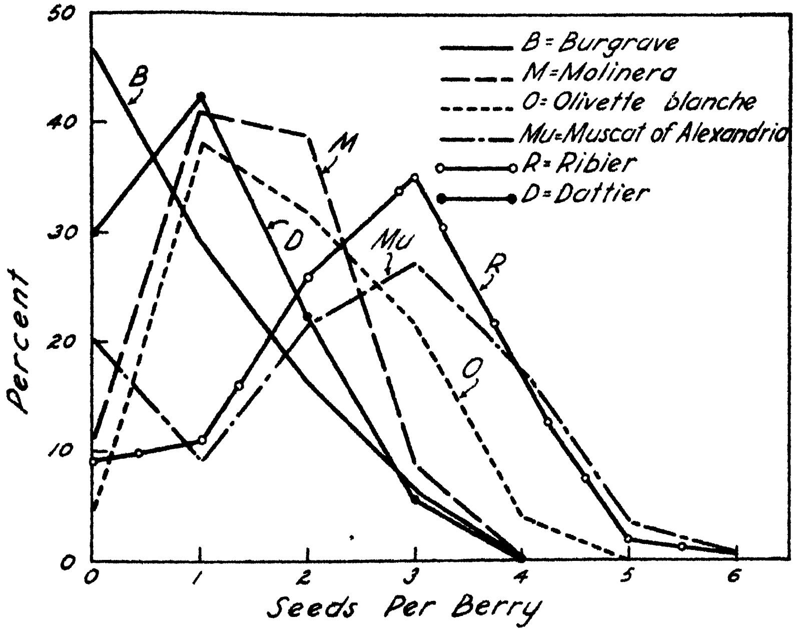

FIG. 1. Distribution of berries as to seed number (hard seed).

duction in seed number per berry the percentage of seedless fruits is small. The question of a relationship between the development of a large proportion of seedless fruits and the reduction in hard seed number can only be resolved by investigating a larger number of varieties and repeating the experiment.

Varieties with elongated berries always show a low frequency of hard seeds per berry. This is true in the present case. The varieties with elongated fruit—Burgrave, Dattier, and Olivette—are all characterized by a low seed number per berry, while the obovoid Muscat and spherical Ribier more nearly approximate a normal distribution. However, it will be noted that varieties with spherical fruit, such as the Molinera, may also show reduction in seed number per berry. Other varieties with fruits approximately spherical are known in which the number of hard seeds per berry is usually one, for example Chardonnay. The distribution of hard seeds per berry may often be typical and constant enough to allow this characteristic to be used in assisting in variety identification. Elongation of the berry and a reduced seed development are in some way related phenomena, since they always occur together, and from the standpoint of the origin of seedless varieties should offer an interesting and profitable field of investigation. The fact that most of the commercially important "seedless" varieties with stenospermic seeds, such as the Sultanina, have elongated fruits is not simply a fortuitous circumstance, but may be allied to the same underlying processes causing reduction in normal seed development and an elongation of the fruit. The question suggested is this: "May not seeded varieties with characteristics of the Burgrave be transition forms toward the seedless types like Sultanina"?

Each variety in this group shows four ovules in the bicarpellate ovary at the time of anthesis, which is the typical condition in *Vitis*. Occasionally in the Muscat of Alexandria, Ribier, and Olivette blanche berries may have three or even four locules instead of the usual two, so that more than four seeds per berry are sometimes found (Fig. 1). In the present samples about six berries per thousand have six hard seeds in the varieties Ribier and Muscat of Alexandria. Multilocular fruits ordinarily show irregular bulges in outline and may be much larger in size than bicarpellate fruits because of greater seed number. If one uses a mean number of four ovules per ovary, then the percentage of these ovules that develop to form hard and stenospermic seeds may be calculated. Reference to Table II shows that a total of only 49.5 per cent of the ovules of Molinera proceed to form either stenospermic

TABLE II—MEAN SEED NUMBER PER BERRY AND THE PER CENT OF OVULES THAT DEVELOPED TO PRODUCE HARD AND STENOSPERMIC SEEDS

Variety	Mean Seed Number			Per Cent of Ovules Developed		
	Hard	Stenospermic	Total	Hard	Stenospermic	Total
Burgrave	0.834	1.574	2.408	20.8	39.4	60.2
Dattier	1.051	1.503	2.554	26.3	37.6	63.9
Molinera	1.488	0.491	1.979	37.2	12.3	49.5
Muscat of Alexandria	2.247	1.220	3.467	56.2	30.5	86.7
Olivette blanche	1.821	0.747	2.568	45.6	18.6	64.2
Ribier	2.470	1.074	3.544	61.8	26.8	88.6

or hard seeds, whereas in the Ribier and Muscat the percentage is 88.6 and 86.7 respectively. The remainder of the ovules, from 50.5 per cent to 11.4 per cent, depending on the variety, remain nonfunctional, and hence do not contribute in increasing the berry size.

In both the Burgrave and Dattier the mean number of stenospermic seeds is greater than the number of hard seeds. The total percentage of ovules that are functional in these two varieties is relatively high, despite the small percentages of seed that approach complete development and form hard seeds. Large berry size is not, therefore, solely a function of normal seed development when intervarietal comparisons are made, even though a high correlation between seed development and berry weight has been shown to exist.

The ovule can be considered nonfunctional if fertilization does not occur. In varieties where this failure is known to occur regularly, such as in the Corinth type varieties (4), or in varieties capable of producing parthenocarpic fruits without any pollination whatsoever (Hunisa), the ovule does not show any appreciable growth after anthesis. It appears, therefore, that fertilization of the ovule is necessary to obtain even a slight amount of seed development.

One of the most surprising results was the complete absence of parthenocarpic fruits in any of the variety samples. It has often been assumed that the smaller-sized berries on clusters of normal seeded varieties, especially those of spherical shape and often referred to as "shot berries" were parthenocarpic and result from vegetative development of the ovary. Thus Stout (6) mentions that three types of berries most likely make up the cluster of *seeded* varieties: (a) seeded berries, (b) stenospermocarpic berries (in this paper called "seedless"), and (c) parthenocarpic berries. Lack of pollination has often been cited as a cause of the development of these "seedless" fruits. Thus the poor set of seeded berries and the large number of small "seedless" berries often reported in commercial vineyards of the Muscat of Alexandria has repeatedly been attributed by various workers to the lack of pollination. Actually, these fruits are not entirely seedless in the varieties investigated here, at least one rudimentary seed being present. As in the Molinera they may be very small in size, yet there is no doubt that even this small amount of seed development has been principally responsible for the enlargement of the berry and the retention of the fruit on the vine to maturity.

Negrul (2) and Stout (6) have concluded that apomictic seed development occurs in the grape. If this were so, it might explain the presence of many of the stenospermic seeds found in the present study. One of the varieties which was used by Negrul to demonstrate apogamic development was the Muscat of Alexandria. The set of castrated flowers that formed seeds in this variety was extremely low. I am inclined to believe that seed sets in varieties that have been emasculated may more than likely be attributed to accidental self or cross-pollination. Repeating the work of Negrul with the varieties Muscat of Alexandria and Aligote at Davis has not confirmed his results. If apomixis were present in the grape, it is indeed strange that ringing of known parthenocarpic varieties such as the Hunisa, which has well-developed and potentially functional ovules, does not produce some rudimentary seed development, especially under this added nutritional stimulus. The implication I wish to make is that the small "seedless" berries found mingled in among berries containing hard seeds in the six varieties studied probably contain at least one fertilized ovule. If this is borne out by cytological verification, then parthenocarpic fruit formation is for all practical purposes absent in the large majority of seeded varieties. Pollination would therefore be necessary to obtain so-called "seedless" berries as well as seeded ones.

In Table III are summarized the mean berry weights and mean seed weights according to type of berry—that is, by considering the seedless and the seeded ones separately. The standard errors of the berry weights range from ±0.01 to ±0.03 grams, those of the seed weights ±0.1 to ±0.5 milligrams. It is evident that the mean weight of the seedless fruits is proportional to the mean weight of the seeded fruits. The varieties with the largest seeded berries also form the largest seedless berries. An interesting relationship is noted when we consider the average seed weights of these two classes of berries. The Ribier has a mean seed weight of 135.97 milligrams for the seeded berries. In other words, although the seeded berry size is equal to the Olivette blanche, a much greater seed development is required. The Dattier, Burgrave, and Molinera have a much smaller seed weight per berry on the average than do the other varieties. A relative measure considering both berry weight and seed weight is a better means of making variety comparisons. A simple method is to use the ratio between seed and berry weights, or one might if necessary calculate the regression coefficients. The ratio of $\frac{\text{berry weight}}{\text{seed weight}}$ gives the approximate number of units of berry flesh produced by one unit of seed development. The value thus obtained is called the seed index number. The figures given have standard errors not exceeding ±0.3 in the seeded column, and ±1.0 in the seedless column (Table III). The Ribier and Muscat of Alexandria are the most inefficient of the six varieties, each producing respectively 44 and 53 milligrams of berry flesh for 1 milligram of seed development. When one considers the seed index numbers of the "seedless" berries, they all appear lower than for berries in which at least one seed approaches the normal size, with the exception of the

TABLE III—BERRY AND SEED WEIGHTS OF SEEDED AND "SEEDLESS" BERRIES AND THE SEED INDEX NUMBER

Variety	Berry Weights (Grams)		Seed Weights (Milligrams)		Seed Index Number	
	Seeded	Seedless	Seeded	Seedless	Seeded	Seedless
Burgrave	8.007	3.235	72.58	2.46	110	131
Dattier	5.497	2.532	51.96	4.36	106	58
Molinera	4.292	1.287	54.83	2.07	78	62
Muscat of Alexandria	5.776	1.882	109.80	9.72	53	19
Olivette blanche	5.978	1.637	100.67	3.00	59	55
Ribier	6.012	2.683	135.97	18.57	44	14

Burgrave, which is able to produce a large amount of berry flesh with a small seed development. The index numbers when applied to the "seedless" berries may be interpreted as a measure of parthenocarpic tendency. Those varieties that can produce "seedless" berries with high index numbers are therefore exhibiting characteristics that approach "seedless" varieties of the Sultanina type. If these tendencies are inherited, then the use of seeded varieties with high index numbers in breeding for new seedless forms should result in the segregation of a large number of seedlings of the desired degree of seedlessness. The use of the Muscat of Alexandria and Ribier as female varieties, despite large berry size, would under the present hypothesis not be expected to yield progeny that segregate many new seedless varieties, because of the high amount of seed development (low index numbers) necessary to produce a "seedless" berry sufficiently large for commercial table fruit.

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Relation of Seed Size to Germination and Early Growth of Mangosteen

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INTRODUCTION

RESULTS of experimental work on the mangosteen, *Garcinia mangostana* L., have been quite variable. A part of these variations appear to be associated with the size of "seed," the general run of which varies considerably. For example, a typical lot of seed used in these experiments varied from 0.1 to 2.2 grams and averaged 1 gram.

Objects of the experiments reported here were (1) to determine the effect of size of mangosteen seed on germination, and the survival and growth of the seedlings, and (2) to determine the effect of size of seedling at transplanting on survival.

EXPERIMENTAL PROCEDURE

Trial I:—Two hundred seeds were weighed to the nearest 0.1 gram and planted in individual gallon cans containing a medium of 90 per cent peat and 10 per cent manure. Drainage was provided in the cans by a layer of loose gravel over a perforated bottom. The plants were grown in a shaded greenhouse for 1 year.

Trial II:—In another trial 157 seeds were separated by weight into groups differing progressively by 0.1 gram. The seed were planted in flats in rows according to their weight class as shown in Fig. 1. The flats contained 2 inches of a mixture of 90 per cent peat and 10 per cent well-rotted manure and a layer of gravel at the bottom for drainage. Plants were grown in a shaded greenhouse.

Trial III:—Seeds in this trial were divided into three size groups of 200 seeds each weighing from: (1) 0.5 to 0.8 gram, (2) 0.9 to 1.1 grams, and (3) 1.2 to 1.6 grams. The few seed falling outside of

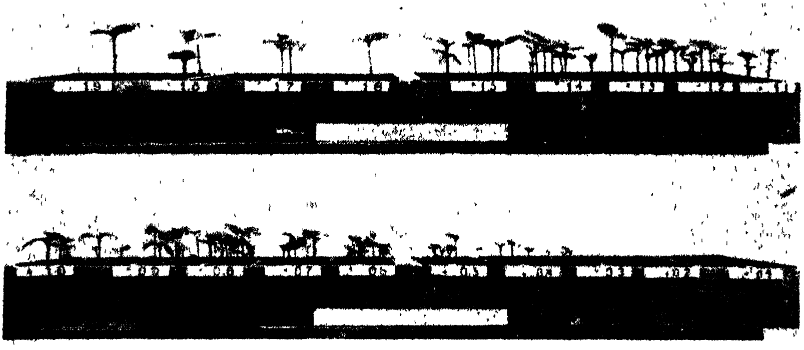

FIG. 1. The effect of seed weight on germination and early growth of mangosteen seedlings in flats. Numbers on flats indicate respective weights of seed in grams. (See Table II.)

these groups were discarded. Each of the three size groups was then divided into four equal sub-groups of 50 seeds each and treated as follows: (a) Planted directly in nursery beds under palm frond shade, (b) planted in gallon cans and transplanted to the nursery bed at the 2-leaf stage, (c) same as (b), but transplanted at 4-leaf stage, and (d) same as (b), but transplanted at 6-leaf stage.

Both the nursery beds and the gallon cans contained a mixture of ⅔ Toa sandy loam and ⅓ well-rotted manure. Drainage was provided in the beds by a layer of gravel 18 inches below the surface; drainage for the cans was provided as described under Trial I. The nursery consisted of 5 plots, each of which was divided into 12 subplots of 10 plants each to accommodate the above treatments. The subplots were independently randomized.

RESULTS

Relation of Seed Size to Germination:—As shown in Tables I and II, germination of seed weighing 0.2 gram or less was very poor. Percentage germination increased rapidly with each 0.1 gram additional seed weight up to 0.6 gram. This increase became gradually less pronounced between 0.6 and 1.0 gram, above which seed germination was about 100 per cent. Seed size, therefore, affected only the percentage germination of seeds weighing less than 1.0 gram.

Relation of Seed Size to Survival:—A similar relationship was found between seed size and survival as in that of the previous case, but at a higher level of seed weight. It is evident from Table I that while germination occurred in seed weighing 0.4 gram or less, the plants all died. Percentage survival increased more or less rapidly for seed weighing from 0.5 to 1.3 grams, above which there was about 100 per cent survival. Thus, the effect of seed size on survival in this

TABLE I—EFFECT OF SEED SIZE ON GERMINATION AND SUBSEQUENT GROWTH OF MANGOSTEEN GROWN IN GALLON CANS IN A SHADED GREENHOUSE (TRIAL I)

Weight Class Grams	Number of Seed	Germination* Per Cent	Survival** (Per Cent)	Average Height Cm
0.1	1	0	—	—
0.2	5	20	0	—
0.3	13	8	0	—
0.4	8	25	0	—
0.5	11	56	18	6.8
0.6	10	40	40	6.8
0.7	10	80	60	9.4
0.8	13	77	62	9.6
0.9	20	90	80	10.1
1.0	20	95	80	10.7
1.1	17	100	94	11.9
1.2	22	95	82	12.4
1.3	19	100	100	12.7
1.4	7	100	100	12.4
1.5	6	100	100	13.9
1.6	4	100	75	13.2
1.7	9	100	100	12.9
1.8	2	100	50	13.9
1.9	2	100	100	13.9
2.0	1	100	100	20.3

*Data taken 53 days after planting.
**Data taken 363 days after planting.

TABLE II—EFFECT OF SIZE OF MANGOSTEEN SEED ON GERMINATION IN FLATS CONTAINING 90 PER CENT PEAT AND 10 PER CENT MANURE (TRIAL II)

Weight Class (Grams)	Number of Seeds Planted	Germination*	
		(Number)	(Per Cent)
0.1	17	0	0
0.2	11	0	0
0.3	9	5	56
0.4	11	4	36
0.5	21	7	33
0.6	13	10	77
0.7	8	6	75
0.8	15	14	93
0.9	9	7	78
1.0	7	6	86
1.1	5	4	80
1.2	8	8	100
1.3	3	3	100
1.4	7	7	100
1.5	7	7	100
1.6	1	1	100
1.7	2	2	100
1.8	1	2	100

*Data taken 47 days after planting.

experiment was noted only for mangosteen seeds weighing 1.3 grams or less.

Results in Table III, as obtained in another trial, also show a gradual increase in survival from progressively heavier seeds, although the percentage of survival was generally lower in this trial.

Relation of Seed Size to Early Growth:—The size of plants after 1 year of growth was positively correlated with the weight of seed. In Table I the data show that there was in general an increase in height of seedling for every 0.1 gram increase in seed weight up to seed weighing about 1.3 grams, above which little effect was noted. The same general results were obtained in Trial III, as shown in Table III, but the amount of growth was less on account of a less favorable environment.

Relation of Seedling Size at Transplanting to Survival and Subsequent Growth:—The percentage survival dropped with an increase in size of plant at the time of transplanting, as shown in Table III. The

TABLE III—SUMMARIZED RESULTS OF SURVIVAL AND GROWTH OF MANGOSTEEN SEEDLINGS FROM LIGHT, MEDIUM, AND HEAVY SEED PLANTED DIRECTLY IN NURSERY BEDS OR TRANSPLANTED FROM CANS AT VARIOUS STAGES OF GROWTH (TRIAL III)

Treatment	Per Cent Survival	Mean Height and Standard Deviation	
		Cm	S. D.
Seed weight class 0.5 to 0.8 gm*	29.0	8.62	±2.32
Seed weight class 0.9 to 1.1 gm*	56.5	10.11	±2.33
Seed weight class 1.2 to 1.6 gm*	67.0	11.04	±2.08
Not transplanted**	48.7	10.67	±2.38
Transplanted at 2-leaf stage**	60.0	9.60	±2.97
Transplanted at 4-leaf stage**	52.0	9.82	±1.91
Transplanted at 6-leaf stage**	42.7	11.22	±2.75

*Includes all plants of this weight group directly seeded and transplanted at three stages of leaf development.

**Average for plants of all seed weight classes.

percentage survival was 60 per cent for the smallest plants (2-leaf), as compared with 52 per cent for the medium-sized plants (4-leaf), and only 42 per cent for the largest plants (6-leaf).

The survival from seed sown directly in the nursery beds was poor. This situation is believed to be associated with the greater difficulty experienced in maintaining uniform moisture conditions in the nursery beds during dry periods.

DISCUSSION

The mangosteen has several peculiarities which tend to influence the results reported here.

The Mangosteen "Seed":—Germination of the mangosteen seed is unique. The seed itself has been called a hypocotyl-tubercle (1) and resembles the germination process of an orchid except that it develops from the inner integument and is, therefore, asexual (2). Swellings occur on opposite ends of the seed. A root develops from one end and a shoot from the other. The original root usually dies, being replaced by a second root system from the base of the stem. There is apparently no differentiated embryo within the seed. Therefore, the ability of the seed to develop a shoot[1] and make its preliminary growth depends chiefly on the amount of stored food available within the seed. The seed can be split and a plant developed from each half, but the food supply is also divided which drastically reduces the chances for success.

The Mangosteen Root;—Roots of this species are devoid of root hairs both in the seedling stage and on mature trees. Thus, the rate of moisture absorption and the volume of the soil which is in contact with the roots is probably lower than with plants with root hairs. As a result, water deficiency can occur more readily in mangosteen than in most plants. The larger plants from the larger seeds in these experiments had a higher survival rate and apparently were better able to withstand drought because of a better developed root system.

The Early Growth:—The mangosteen like the orchid appears to have difficulty in growth between the time the seed reserves are exhausted and the plant becomes fully established and initiates further growth. During this period growth may stop, sometimes for several years.

Because of these peculiarities the effect of seed size is particularly important in mangosteen. The seed supplies the energy for generation and differentiation of the embryo, the development of two root systems and the development of the plant until the synthetic mechanism can become established. The effect of seed size is not masked by independent growth of the mangosteen seedling during the first year.

SUMMARY AND CONCLUSIONS

Experiments were conducted to determine the effect of size of seed on germination, survival, and subsequent growth of mangosteen seedlings. Also, experiments were conducted to determine the effects of size of plant at transplanting upon survival.

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[1] Shoot appearance on the surface of the soil was used as a criterion of germination in these tests.

Percentage seed germination increased with each 0.1-gram increase in seed weight from 0.2 to 1 gram, above which there was little or no effect.

The number of seedlings surviving and their amount of growth increased with seed weight to a maximum of about 1.3 grams, above which there was no apparent effect. Thus, it appears that experimentation can be carried on with mangosteen seed weighing 1.3 grams or more without complications from effect of seed size.

Mortality of seedlings was greater for plants transplanted at the 4- and 6-leaf stage of development than at the 2-leaf stage.

The peculiarities of the mangosteen are described and discussed in relation to the results obtained.

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The Use of Root-Promoting Substances in the Propagation of Olives by Soft-Wood Cuttings

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One of the most valuable uses of the various growth-promoting substances is the rooting of cuttings taken from plants which are difficult or impossible to root without such treatment. The olive is such a plant. Most olive varieties will form roots to some extent without treatment; but others, notably the Sevillano variety, are apparently impossible to root without some type of "hormone" treatment. As a large proportion of olive trees grown in California are propagated by softwood cuttings, it was felt that information on the use of root-promoting materials would be of value.

Preliminary Test:—To gain more information on the best environmental conditions for propagating olive cuttings a preliminary test, involving about 1,000 cuttings, was started in September, 1945. The rooting medium used was pure sand. Four conditions were maintained: (a) bottom heat with high humidity; (b) bottom heat with low humidity; (c) no bottom heat, with high humidity; and (d) no bottom heat, with low humidity. The bottom heat was secured by means of thermostatically controlled electric soil cables, which held the temperature at the bottom of the cuttings at about 75 to 80 degrees F. When no bottom heat was used, the temperature of the sand varied from 60 to 70 degrees F. The high humidity was maintained by covering the propagating bench tightly with greenhouse sash, which gave a relative humidity of 90 to 100 per cent. The low-humidity treatment was provided by exposing the cuttings to the greenhouse atmosphere, ranging in relative humidity from 20 to 80 per cent. Two types of cuttings were used in this test: "tip" cuttings, taken from the terminal 4 to 5 inches of the previous summer's growth; and "stem" cuttings, taken immediately below the part used for tip cuttings, and usually a little more woody and matured. The stem cuttings are shown in figures 1 and 2. Three varieties were used in this test: Mission, Manzanillo, and Sevillano. The results are given in Table I.

Although in this test no very high rooting percentages were obtained, the Mission variety was the easiest to root, followed by Manzanillo and Sevillano. With this last variety, no rooted cuttings were

Table I—Test of Types of Environment and Types of Cuttings. Per Cent of Olive Cuttings Rooted After 16 Weeks. September 26, 1945, to January 16, 1946

Variety	Bottom Heat (75 to 80 Degrees F)				No Bottom Heat (60 to 70 Degrees F)			
	High Humidity (90 to 100 Per Cent)		Low Humidity (20 to 80 Per Cent)		High Humidity (90 to 100 Per Cent)		Low Humidity (20 to 80 Per Cent)	
	Tip	Stem	Tip	Stem	Tip	Stem	Tip	Stem
Mission	19	26	0	0	0	6	0	0
Manzanillo	0	8	0	0	0	11	0	0
Sevillano	0	0	0	0	0	0	0	0

obtained. In general, better results were obtained when bottom heat was used together with high humidity. The Manzanillo, however, gave slightly better results without bottom heat; but the difference is probably not significant. Wherever rooting occurred, the stem cuttings proved superior to the tip cuttings.

Tests with Several Root-Promoting Substances:—In January, 1946, another series of cuttings were started. They were all "stem" cuttings and were placed under conditions of high humidity, with bottom heat. Three varieties were used; Mission, Manzanillo, and Sevillano. About 1,000 cuttings were involved with approximately 25 cuttings per treatment. The treatments included three commercial preparations and five pure chemicals, as listed in Table II. The pure chemicals were used at two concentrations, 40 and 200 ppm, and were first dissolved in a small amount of ethyl alcohol, which was then mixed with the required amount of water to give the desired concentration. The cuttings were soaked in the solutions for 24 hours before being placed in sand in the propagation bed.

Hormodin, one of the commercial preparations, is a powder containing indolebutyric acid; Rootone, another commercial product, is also a powder containing alpha naphthylacetamide. Treatment with these materials involved dipping the lower end of the cuttings directly in the powder just after a fresh cut was made. The cuttings were then set immediately in the propagating bed. The Vitamin B_1 + used was a commercial preparation which contained Vitamin B_1 —0.15 per cent, Vitamin B_2 0.015 per cent, Vitamin B_6 0.0024 per cent, calcium pantothenate 0.01 per cent, and niacin 0.007 per cent. This material was used at the recommended concentration.

TABLE II—Treatment With Root-Promoting Substances. Per Cent of Olive Cuttings Rooted After 10 Weeks. January 24, 1946, to April 4, 1946

Material	Concentration	Variety		
		Mission (Per Cent)	Manzanillo (Per Cent)	Sevillano (Per Cent)
Control	—	28	8	0
Hormodin	No 2	50	18	4
Rootone	—	26	18	4
Vitamin B_1 +	—	1	0	0
Indolebutyric acid	40 ppm.	30	30	20
Indolebutyric acid	200	30	17	4
Indoleacetic acid	40	7	3	0
Indoleacetic acid	200	14	0	8
Naphthaleneacetic acid	40	20	11	10
Naphthaleneacetic acid	200	16	8	9
Naphthalene acetamide	40	20	4	—
Naphthalene acetamide	200	4	7	—
Indolepropionic acid	40	30	25	5
Indolepropionic acid	200	4	18	0

With the Mission variety, Hormodin (indolebutyric acid) was the only material that showed an appreciable increase in rooting over the control lot. The Manzanillo variety showed better rooting with several of the chemicals, notably indolebutyric acid at 40 ppm.

No Sevillano cuttings rooted unless treated with a root-promoting substance. Of the materials used, indolebutyric acid at 40 ppm gave the greatest increase in rooting over the control lot with this variety. Vitamin B_1 + caused a decrease in the number of roots formed with the three varieties used.

Judging from the results of this test, of the eight materials used indolebutyric acid offered the most promise in rooting olive cuttings.

Tests with Indolebutyric Acid:—In April, 1946, another set of olive cuttings using the same three varieties was started to determine the optimum concentration of indolebutyric acid for rooting. About 750 cuttings were included in this series with approximately 25 cuttings per treatment. The "stem" type of soft-wood cuttings was used, and the cuttings were grown in sand with bottom heat under conditions of high humidity. The cuttings in this set were secured just before bloom; the inflorescences were well developed, but the flowers had not opened. The inflorescences were removed when the cuttings were made. Two concentrations of Hormodin were included in this test as well as Rootone. Six concentrations of indolebutyric acid were used—from 400 ppm to 12 ppm, as shown in Table III.

TABLE III—TREATMENT WITH ROOT-PROMOTING SUBSTANCES. (CONCENTRATION SERIES). PER CENT OF OLIVE CUTTINGS ROOTED AFTER 10 WEEKS. APRIL 24, 1946, TO JULY 3, 1946

Material	Concentration	Variety		
		Mission (Per Cent)	Manzanillo (Per Cent)	Sevillano (Per Cent)
Control	—	0	3	0
Hormodin	No. 2	10	4	0
Hormodin	No. 3	32	21	0
Rootone	—	5	7	9
Indolebutyric acid	400 ppm.	4	38	4
Indolebutyric acid	200	14	55	14
Indolebutyric acid	100	29	70	18
Indolebutyric acid	50	67	79	33
Indolebutyric acid	25	70	69	42
Indolebutyric acid	12	76	38	14

With the Mission variety, indolebutyric acid at 12 ppm gave the highest percentage of cuttings rooted. This same material at 50 ppm, although it caused fewer cuttings to root, gave a larger number of roots per cutting. This situation is shown in Figs. 1 and 2.

Indolebutyric acid at 50 ppm caused 79 per cent of the Manzanillo cuttings to root, in comparison with 3 per cent of the untreated cuttings. This same material at 25 ppm gave the best results with the Sevillano variety, causing 42 per cent of the cuttings to root. In none of the tests conducted did any Sevillano cuttings root unless treated with some root-promoting substance.

In comparing the control lots of cuttings of the three series of tests, one sees from Table IV that fewer roots were formed in the spring test (April 24 to July 3) than in the fall and winter tests (September 26 to January 16 and January 24 to April 4). After treatment with root-promoting substances, however, relatively high percentages of cuttings formed roots in the late spring series.

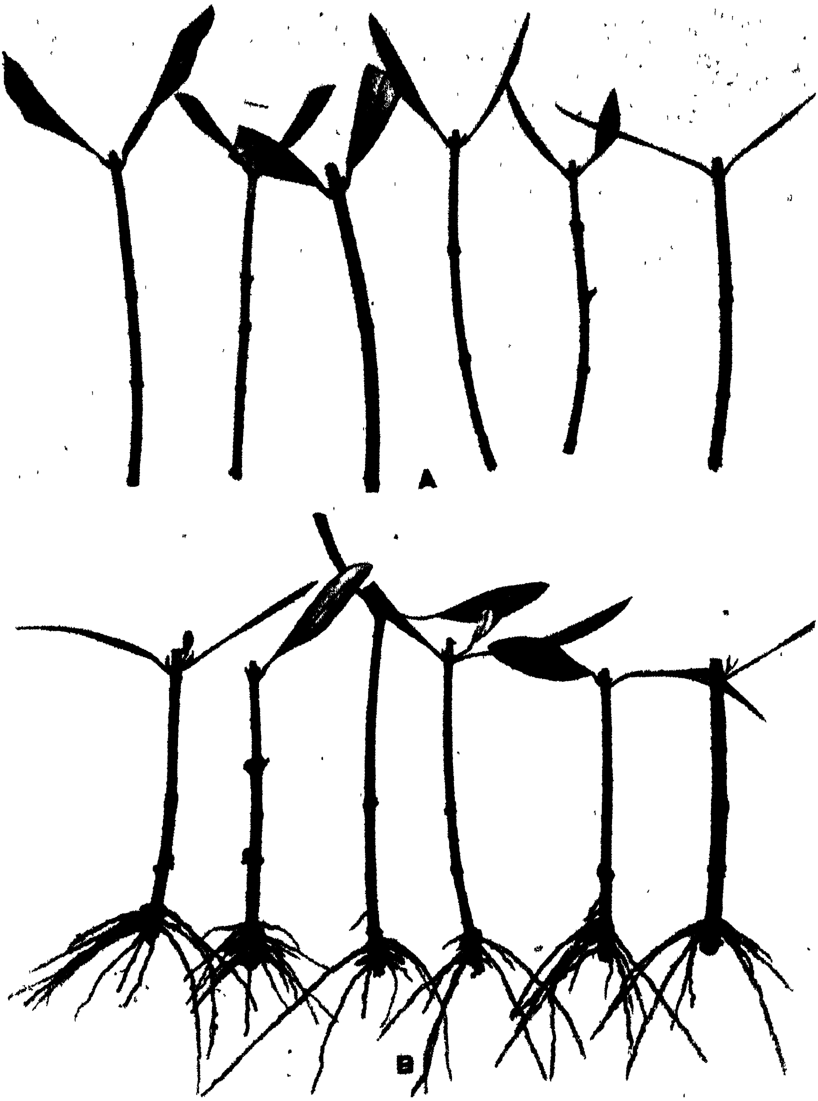

FIG. 1. Soft-wood olive cuttings, Mission variety. (A) control. (B) cuttings treated with indolebutyric acid, 50 ppm.

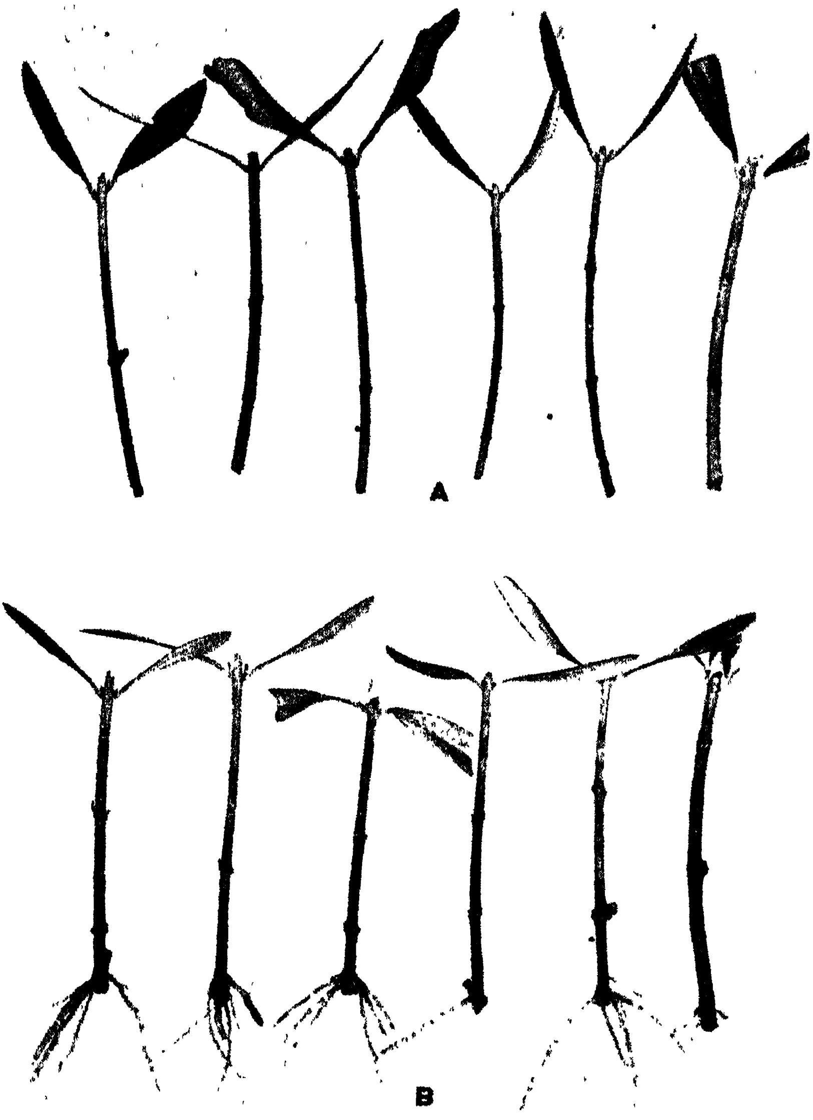

FIG. 2. Soft-wood olive cuttings, Mission variety. A, control. B, cuttings treated with indolebutyric acid, 12 ppm.

TABLE IV—COMPARISON OF THE PERCENTAGE OF CUTTINGS ROOTED WHEN TAKEN AT THREE DIFFERENT TIMES DURING THE YEAR. (CONTROL LOTS OF "STEM" CUTTINGS WITH BOTTOM HEAT AND HIGH HUMIDITY)

Variety	September 26—January 16 (16 Weeks) (Per Cent)	January 24—April 4 (10 Weeks) (Per Cent)	April 24—July 3 (10 Weeks) (Per Cent)
Mission	26	28	0
Manzanillo	8	8	3

CONCLUSIONS

On the basis of three series of tests carried out on methods of rooting soft-wood olive cuttings, the following results were obtained:

1. Higher percentages of cuttings formed roots when conditions of bottom heat and high humidity were maintained.
2. An appreciable benefit was obtained in the rooting of soft-wood olive cuttings when certain root-promoting substances were used. This statement applies in particular to indolebutyric acid at 25 to 50 ppm.
3. Untreated olive cuttings formed roots more readily when taken in the fall and winter months than in late spring. When treated with root-promoting substances, however, very good results were obtained with cuttings taken in the spring.

Rooting Cuttings and Germinating Seeds Under Fluorescent and Cold Cathode Lighting

By V. T. Stoutemyer and Albert W. Close, *U. S. Department of Agriculture, Glenn Dale, Md.*

Insulated opaque structures offer many advantages in the rooting of cuttings, if suitable artificial light can be supplied at reasonable cost. Accurate temperature control is assisted at all seasons of the year and the cost of heating is greatly reduced. The humidity can be maintained at a high level without mechanical apparatus. The construction cost of such structures can be relatively low and space can be saved by the vertical tiering of the plants, since artificial light sources are used. Light of any desired spectral quality may be applied and also the periods of illumination may be regulated precisely.

Bell jars and closed Wardian cases do not eliminate completely rapid fluctuations in relative humidity or in temperature which are due to solar radiation. This is illustrated in Fig. 1 which shows the

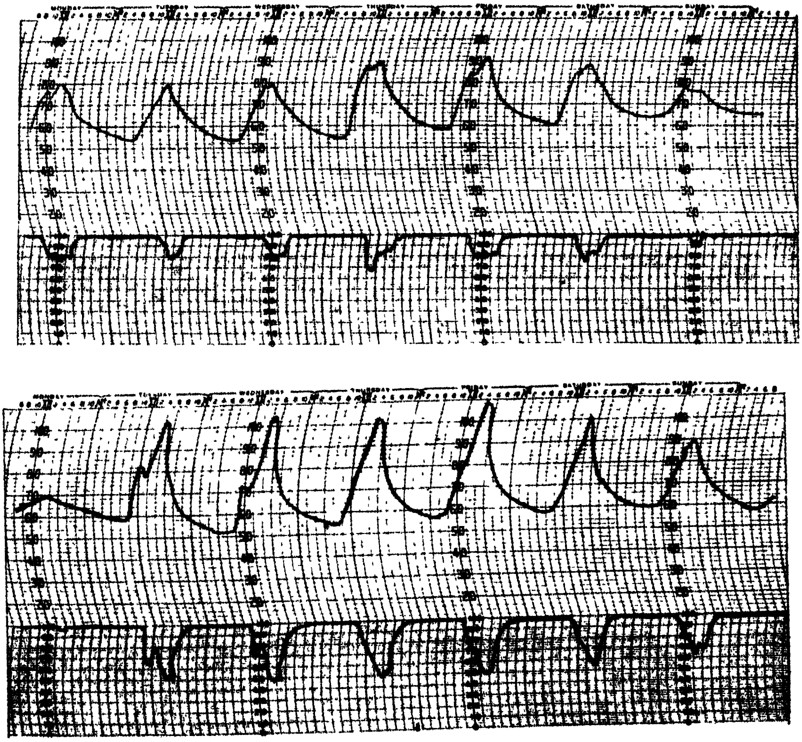

Fig. 1. Temperature and relative humidity within a bell jar. Upper chart: Maximum light intensity, 2000 foot candles. Lower chart: Maximum light intensity, 4000 foot candles. (Upper line of each chart represents temperature, and lower line, humidity.)

results of an experiment in which a bell jar was placed over a water surface in a greenhouse shaded to admit a maximum of about 2000 foot candles at noon of a bright day. The following week the shading was arranged to admit a maximum of about 4000 foot candles. The weather was sunny during the period of the test. The charts from a hygro-thermograph placed within the bell jar showed that in the house with the lower light intensity, the relative humidity was sometimes as low as 80 per cent, and with a maximum of about 4000 foot candles, it was as low as 50 per cent. Obviously, the maintenance of uniform, well controlled conditions within conventional greenhouses demands elaborate and costly air conditioning equipment.

In contrast, the relative humidity within a semi-underground opaque propagating house fluctuated slightly. Fig. 2 shows charts for a week in each of two different seasons of the year.

The insulation of this structure was not perfect and some diurnal fluctuations of temperature may be observed. However, these did not reduce the relative humidity which remained near saturation. Wetting of the walks or walls was not needed to maintain this high value.

During the winter, some intermittent heating with a small one electric heater was necessary. This caused slight reductions in the relative

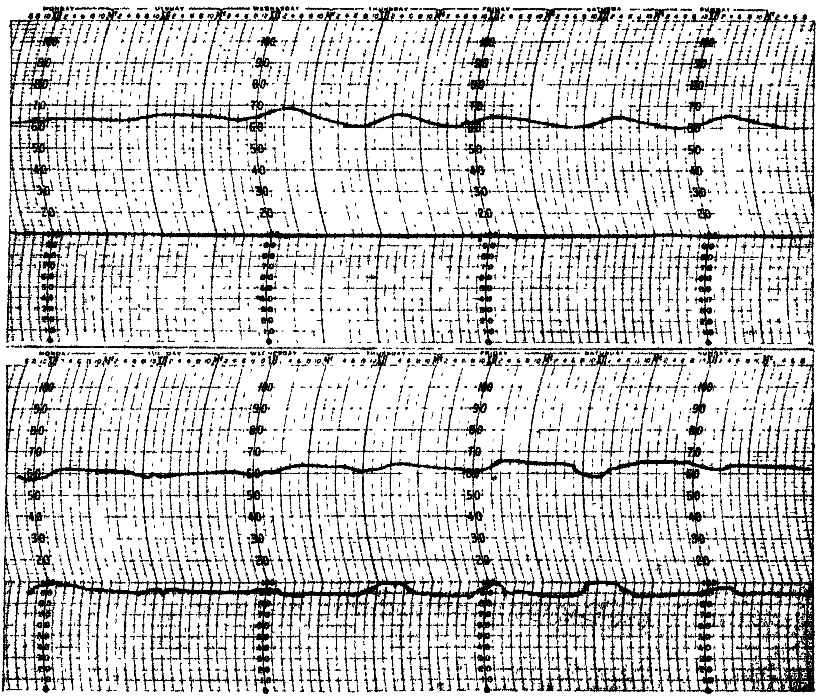

FIG. 2. Temperature and relative humidity within an opaque propagating house. Upper chart: Week beginning April 16, 1945. Lower chart: Week beginning February 4, 1946. (Upper line of each chart represents temperature and lower line, humidity.)

humidity, but the chart shows that these would have little, if any, significance from a practical standpoint.

ROOTING OF CUTTINGS UNDER HOT CATHODE FLUORESCENT LAMPS

The practicability of rooting greenwood cuttings of plants in opaque structures under hot cathode fluorescent lamps has been demonstrated by Stoutemyer, Close, and O'Rourke (12). The available lamps of this type produce about two and one half times as many lumens per watts consumed as tungsten filament lamps, and have certain other advantages which adapt them to use in the propagation of plants. They can be used in relatively confined spaces without injury to the plants because of their low heat production. They also offer an efficient means of production of light of various colors without the use of filters which waste energy. Rohrbaugh (8) and also Flint and Moreland (2) have studied the responses of plants to various colors of light from fluorescent lamps. Naylor and Gerner (7) and Hamner (3) obtained normal plant growth under lamps of this type. The spectral distributions of the various fluorescent lamps (General Electric) used in these tests have been published by Inman (4).

The object of the present study was primarily to evaluate the potential usefulness of various available light sources for operations in plant propagation. Therefore no attempt was made to equalize the quanta intensities of the light, and all of the lamps in a given experiment were placed at equal distances from the seedlings or cuttings. Readings of the intensities were taken with a Weston illumination meter for purposes of reference only and those given for the colored lamps were made without the appropriate correction filters.

Since the light intensity changes during the useful life period of the lamps, and since the spectral quality may change also, tubes were replaced at the beginning of experiments when practicable, or tubes having equal hours of operation were matched.

ROOTING OF CUTTINGS IN OPAQUE MINIATURE PROPAGATING CASES

Several different types of opaque propagating cases using fluorescent lamps as an exclusive light source have been constructed at the U. S. Plant Introduction Garden, Glenn Dale, Maryland. The simplest type consisted of a flat-topped frame covered with glazed sash or with a glass substitute, with a fluorescent lamp. Cases of this type were made in lengths from 4 to 7 feet and in widths from 2 to 3 feet. One or two doors hinged at the top were provided for the front of the cases. Soil heating cables, thermostatically controlled, were preferred for supplying bottom heat to the rooting medium. Because of wartime scarcities, another type of heating was also used, in which an air space below the rooting medium was heated by a 100-watt socket heater or a carbon filament lamp. The socket for the heater was mounted on one side wall of the case beneath the rooting medium and a metal guard was provided to aid in preventing the entrance of drainage water. When this type of heating was used, the rooting medium was placed in metal flats which were held snugly in place by brackets

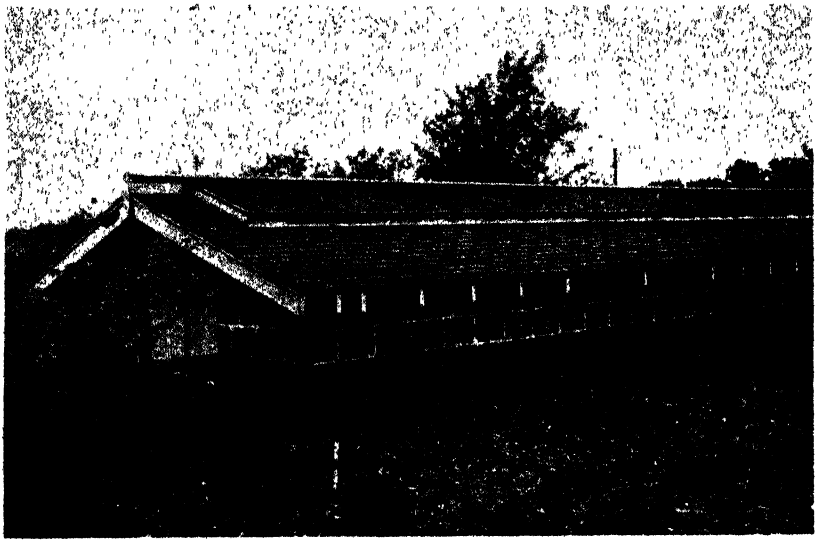

FIG. 3. Exterior view of washing shed used for propagation by artificial light.

around the sides. Various illuminants were used, ranging from one 30- or 40-watt tube to two 40-watt tubes.

The use of materials having good insulation values for the walls was found to aid the operation greatly since condensation on the inner surfaces of the walls was reduced, thereby increasing the atmospheric humidity.

Two variants of these cases deserve mention. In one, the cuttings in the rooting medium were separated from the lamp by a glass partition. Any desired amount of the heat from the lamp could be eliminated by opening the door for ventilation, without reducing the humidity about the cuttings. Another variant consisted of a case arranged in vertical tiers. The rooting medium was placed in metal flats for removal and convenient handling when setting or removing cuttings. A case of this type was constructed in which the heat of the lamp was conserved to provide bottom heat for the rooting medium above. This arrangement makes possible a great saving in space.

Two of the miniature cases placed back to back had a common soil heating cable to assure identical conditions within both. This combination was used for studies of effects of different day-lengths on rooting or for comparisons of the effect of various colors of light.

The rooting medium is highly important for success with this type of propagation and must combine good water retention with adequate aeration. The value of expanded vermiculite, a micaceous mineral expanded by heat, as a rooting medium has been shown by Stoutemyer (10). The house insulation grade, usually with some of the coarser materials screened out, was used. Vermiculite should be watered several times the day before using as the pore spaces fill rather slowly.

The light weight of vermiculite also makes it advantageous for use with trays or flats in a tiered arrangement. The drainage is excellent with vermiculite.

A mixture of two parts of peat moss and one part of vermiculite has produced exceptionally heavy rooting of acid soil plants such as azaleas. Peat moss alone or shredded sphagnum moss, when carefully watered, have given excellent results, but rooting has generally been inferior with sand.

In this system of propagation, the watering needed has often been so infrequent that the advantages of automatic watering are doubtful. However, three different systems were tried with vermiculite, although experimentation has not been continued over a sufficiently long period of time to permit an unqualified recommendation. One cutting bench filled with vermiculite was watered for 5 weeks with wicks of spun glass and received no other attention during this period. Subirrigation with intermittent levels and also watering by capillarity from a constant water level have been tried. The results with the latter system were excellent at first, but subsequently some injuries were encountered with cuttings which suggested that the aeration had deteriorated. Possibly some of the air spaces were becoming waterlogged.

COMPARISON OF ROOTING UNDER ARTIFICIAL LIGHT AND IN THE GREENHOUSE

The miniature propagating cases and also larger opaque chambers when operated carefully have given results which consistently equal those obtainable in elaborate and expensive propagating houses. Results of a few tests are shown in Table I in which a propagating case in a north lean-to greenhouse was used for comparison. This was provided with thermostatically controlled soil heating cable and was doubtless the most satisfactory location for propagation available in the greenhouse range. The light intensities in the propagating case reached a maximum of about 250 foot candles. Temperatures of about 73 to 75 degrees F were maintained in the rooting medium. Naturally some fluctuations in the air temperature of the greenhouse were unavoidable. The temperature and humidity in the miniature cases showed a remarkable uniformity, and charts from recording instruments showed practically straight lines and the light intensity did not vary.

Although in some instances the rooting was superior in the greenhouse the opposite was often true. The rooting in the opaque miniature cases was notable for rapidity. Cuttings of various types of *Citrus* were rooted in 2 weeks, and cuttings of carnation and *Acalypha wilkesiana* var. *macrophylla* Hort. rooted in ten days and were ready for potting in less than 2 weeks. Rooting of cuttings of the French hybrid lilac, Mme. Lemoine, was noticed in 1 week. Cuttings of various hollies and *Thuja*, *Taxus*, and *Retinospora* among coniferous evergreens were rooted, and also other woody plants. Cuttings of many kinds of florists' plants, including camellia, dahlia, carnation, and chrysanthemum responded well. The data presented in Table II

TABLE I—A Comparison of Rooting of Cuttings Under Artificial Light and in the Greenhouse (100 Cuttings per Treatment Unless Otherwise Noted)

Light Quality and Intensity (Foot Candles)	Period of Illumination	Number of Cuttings Rooted			
		Total	Heavy	Medium	Light
Cinchona succirubra Pavon.—Oct 25 to Nov 9					
Daylight 110	Continuous	92	33	28	31
Greenhouse		83	—	—	83
Cinchona ledgeriana Moens.—Oct 25 to Nov 13					
Daylight 110	Continuous	57	14	7	36
Greenhouse		85	—	2	83
Cinchona succirubra.—Nov 13 to Nov 27					
Daylight 110	Continuous	97	35	14	48
Daylight 110	16 hrs daily	95	27	25	43
Greenhouse		81	—	—	81
Cinchona ledgeriana—Nov 13 to Dec 4					
Daylight 110	Continuous	96	56	18	22
Daylight 110	16 hrs daily	93	29	32	32
Greenhouse		97	29	11	57
Cinchona sp. (40 Cuttings Per Treatment)—Apr 16 to May 14					
White 400	Continuous	32	5	18	9
Greenhouse		25	—	2	23
Forsythia ovata Nakai.—Apr 17 to May 8					
White 400	Continuous	41	19	5	17
Greenhouse		50	22	10	18
Forsythia intermedia var. densiflora Koehne (40 Cuttings per Treatment)— May 2 to May 17					
White 400	Continuous	31	14	5	12
Greenhouse		20	—	4	16
Citrus Limon (L.) Burm. f. (20 Cuttings Per Lot)—Dec 11 to Dec 30					
Daylight 110	Continuous	20	—	11	9
Daylight 110	16 hrs daily	19	—	5	14
Greenhouse		6	—	—	6

illustrate the extent of rooting obtained with various types of *Citrus* and its relatives obtainable in short periods. In these trials, rooting under the 3500 degree white and the daylight lamps was compared, using a temperature of 75 degree F in the rooting medium. The cuttings in this test received 16 hours light daily. Twenty cuttings were used per lot. When a treatment with growth substance was used, the bases of the cuttings were dipped quickly in a solution of 50 per cent ethyl alcohol containing 5 mg of potassium indole butyrate (designated as KIB) per milliliter.

These experiments demonstrated that heavier rooting was obtained under the 3500-degree white tubes than under the daylight tubes in which the proportion of blue light is relatively greater.

INFLUENCE OF PHOTOPERIOD ON ROOTING OF CUTTINGS

Continuous illumination was used in most of these experiments with rooting of cuttings and has given satisfactory results with all of the numerous species used, although in some instances the 16 hour daily illumination was preferable. Continuous illumination is simple

TABLE II—ROOTING OF CUTTINGS UNDER 3500 DEGREE WHITE AND DAYLIGHT FLUORESCENT LAMPS (ROOTING PERIOD DEC. 7 TO DEC. 30)

Color of Light	Treatment With Growth Substance	Number Cuttings Rooted	Total Number Roots	Total Length of Roots (Cm)
		Severinia buxifolia (Poir.) Tenore		
Daylight	None	16	20	52
White	None	13	24	89
Daylight	KIB	13	37	79
White	KIB	18	45	143
		Citrus mitis Blanco		
Daylight	None	12	18	44
White	None	14	30	78
Daylight	KIB	12	20	48
White	KIB	16	48	205
		Citrus aurantium L.		
Daylight	None	3	3	3
White	None	9	9	16
Daylight	KIB	0	0	0
White	KIB	4	9	24
		Citrus limon		
Daylight	None	15	33	133
White	None	18	43	258
Daylight	KIB	18	66	299
White	KIB	20	82	436

and eliminates the need of manual operation or a time switch. The useful life of hot cathode tubes is often lengthened greatly by infrequent starting. On the other hand, the use of shorter photoperiods economizes on electric current. Moshkov and Kocherzhenko (6), working with supplementary lighting on cuttings, believed that continuous illumination was more favorable to rooting than intermittent lighting.

The use of 8 hours of illumination daily appeared to be less satisfactory although an exception may be noted. Cuttings of *Carissa bispinosa* (L). Desf. placed in cases in February under 30 watt lamps were heavily rooted and were in excellent condition when removed in August. The differences in rooting between cuttings receiving 8, 16 and 24 hours of light per day were small, although those receiving only 8 hours illumination per day were probably best. This tropical species may be considered as somewhat difficult to root. Many other examples could be cited showing that cuttings can be maintained in excellent condition over long periods of time under fluorescent lamps.

Some interactions of species with photoperiod were observed. Whether these remain constant or are conditioned by nutritional conditions is uncertain at present. The rooting of *Cinchona ledgeriana* was much heavier under continuous illumination than under a 16 hour daily light period. On the other hand, there was little difference in the rooting of cuttings of *C. succirubra* under the two photoperiods.

Interactions of treatment with growth substance on photoperiod were also noticed, although time and space available did not permit a detailed study. Cuttings of *Acalypha wilkesiana* var. *macrophylla* rooted more heavily under 16 hours daily illumination than under continuous lighting. However, when treated with growth substances, the responses were about the same in both lots. Untreated cuttings of rough lemon rooted similarly under the two photoperiods, but when treated with growth substance, by far the best rooting was under continuous illumination. Untreated cuttings of Chinotto orange likewise rooted similarly under the two photoperiods, but the best response following a treatment with growth substance was in the 16 hour photoperiod.

Rooting of Cuttings in Opaque Shed

Since the 3500-degree white tubes were found to be superior for the rooting of cuttings they were used as the controls in later experiments with lamps of different colors, which were conducted in a semi-underground shed constructed of cinder blocks illustrated in Fig. 3. This had served originally as a shed for washing and heeling-in nursery stock, and was 36 feet long and 10 feet wide. The roof was well insulated, except for a long skylight, which was covered with insulating board during these experiments. A shaft originally used as a chimney for a heater provided an intake of air. At the opposite end, an electrically driven ventilating fan was connected to a time clock which could be set to any desired schedule. Conventional greenhouse benches 3 feet wide were placed along the two long walls. The bottoms of the benches were made of ¼-inch hardware cloth over wooden cross stringers. The benches were filled with a medium grade of vermiculite, which was prepared by screening out the larger particles from the house insulation grade with a ⅓-inch screen. Lead sheathed soil heating cables were placed in the rooting medium and were controlled by thermostats to maintain temperatures slightly above 70 degrees F.

Conventional hot cathode fluorescent lamps were used over the benches on one side of this house. The light from the various units was confined to the appropriate section of the propagating bench by means of plywood partitions painted with white flat paint as shown in Fig. 4. An industrial type fixture containing two 40-watt tubes was suspended over each of the sections.

In the first trials the two parallel 40-watt tubes were only one foot above the cuttings, and the light intensities on the cuttings ranged from 400 to 500 foot candles with most of the colors used. Since occasional wilting and bronzing of foliage was noticed immediately under the lamps, the distance was increased to 18 inches which gave around 300 foot candles. Since the rooting was improved by the decrease in the intensity, a distance of 2 feet was tried with excellent results. This distance was used in many of the later experiments. The light readings usually ranged from 150 to 200 foot candles.

Cuttings remained in excellent condition for many months and rooted well under even lower intensities. A quantitative study of the relationship between light intensity and the speed and heaviness of rooting of cuttings of various species was not undertaken, but would be useful.

FIG. 4. Interior view of washing shed used for propagation by artificial light.

Most of the experiments here reported were conducted during the summer, when the temperatures often went somewhat higher than desired. Doubtless a structure completely underground, with improved insulation would have been preferable. Experiments were continued through the winter of 1945–46, and the amount of heat necessary to maintain satisfactory temperatures was small. Supplementary heat from a small one kw electric heater was used after early December but often this was operated only intermittently. Usually the temperatures ranged from 60 to 65 degrees F but on several sub-zero nights went as low as 51 degrees F. With better insulation even less heat would have been needed. Fan ventilation was not used during the winter. The structure was entered daily, but whether or not additional ventilation to provide carbon dioxide would have been beneficial is not known.

The results of tests with the blue and green lamps are shown in Table III. White lamps were used as the control. Six replicated lots of ten cuttings each were used for each color. Continuous illumination was provided, and in some instances a mixture of one part of indolebutyric acid in 1000 parts of talc was applied to the bases of the cuttings. This treatment is designated in the Table as IB.

Both the number of cuttings rooted and the weights of roots produced were tested for significance of mean differences by the "t" test. These results show that the blue light was generally inferior in producing rooting of cuttings and explain the usual superiority of the 3500 degree white lamps over daylight lamps, since the latter contain more of the blue end of the spectrum. Cuttings of an occasional

TABLE III—ROOTING OF CUTTINGS UNDER FLUORESCENT LAMPS

Color of Light	Intensity in Foot Candles	Treatment With Growth Substance	Number of Cuttings Rooted				Total Root Weight (Mg)
			Total	Heavy	Medium	Light	
			Forsythia ovata—Apr 17 to May 8				
White	420	None	41	19	5	17	533
Green	420	None	39	22	8	9	733
Blue	420	None	29*	7	9	13	424
White	420	IB	50	25	11	14	1,094
Green	420	IB	50	25	10	15	1,074
Blue	420	IB	53	23	16	14	851**
			Spiraea sp.—Apr 24 to May 15				
White	420	None	33	11	7	15	—
Green	420	None	13*	3	4	6	—
Blue	420	None	18*	7	8	3	—
White	420	IB	43	29	3	11	—
Green	420	IB	32**	19	7	6	—
Blue	420	IB	18*	9	4	5	—
			Ligustrum ovalifolium Hassk.—May 18 to June 10				
White	220	None	54	26	18	10	638
Green	220	None	43**	3	21	19	257**
Blue	220	None	12**	--	6	6	54**
White	220	IB	48	20	18	10	481
Green	220	IB	54	25	13	16	431
Blue	220	IB	22**	5	9	8	220**
			Citrus limon—Jun 1 to Jun 23				
White	220	None	58	18	29	11	1,538
Green	220	None	54	10	26	18	1,299
Blue	220	None	51	11	25	15	1,194
			Tripterygium wilfordii var. exesum—May 29 to Jun 28				
White	220	None	60	20	14	26	
Green	220	None	56	25	16	15	—
Blue	220	None	58	20	14	24	—

*Indicates significant mean difference (5 per cent probability) in comparison with white

**Indicates highly significant mean difference (1 per cent probability) in comparison with white.

species rooted practically normally under the blue light; *Tripterygium wilfordii* var. *exesum* Hort. was an example.

Unquestionably the green tubes were superior to the blue and often approached the 3500-degree white lamps closely in performance. The condition of the foliage under the green light at times seemed to be slightly inferior to that under the white light, although further observation will be necessary for verification. Flint and Moreland (2) obtained virtually normal growth of plants under green fluorescent lamps, but found that starch grains accumulated in the guard cells about the stomata, but were absent from the leaf mesophyll.

Similar tests were conducted with pink, gold, red, soft white, and a combination of one pink and one blue lamp. In these tests five replicated lots each having 20 cuttings were used under each light. The results are shown in Table IV.

These data when tested statistically revealed no significant differences in comparisons of pink or gold lamps with the 3500-degree white lamps, notwithstanding the somewhat lower intensities of the two former colors as measured by a Weston Illumination meter. The red lamps produced a fair amount of rooting considering their very low efficiency. The poor rooting under the mixture of blue with pink

TABLE IV—ROOTING OF CUTTINGS UNDER FLUORESCENT LAMPS

Color of Light	Intensity in Foot Candles	Treatment With Growth Substance	Number of Cuttings Rooted				Total Root Weight (Mg)
			Total	Heavy	Medium	Light	
Forsythia intermedia var. spectabilis (Koehne) Spaeth—May 19 to Jun 4							
White	220	None	99	74	19	6	2,381
Pink	180	None	100	73	24	3	2,109
Red	30	None	98	3	88	8	1,046**
White	220	IB	95	53	25	17	2,328
Pink	180	IB	100	93	6	1	2,572
Red	30	IB	98	4	81	13	1,017
Weigela floribunda (Sieb. and Zucc.) C. A. Mey.—May 25 to Jun 20							
White	220	None	67	9	14	44	—
Pink	180	None	70	29	14	27	—
Red	30	None	19**	—	3	16	—
Ligustrum ovalifolium—May 18 to Jun 16							
White	220	None	80	25	27	28	606
Pink	180	None	69	15	21	33	336
Red	30	None	77	—	31	46	199**
White	220	IB	81	34	18	29	722
Pink	180	IB	981	41	19	21	670
Red	30	IB	7	—	44	35	261**
Ligustrum ovalifolium—Jun 26 to Aug 2							
White	220	None	84	44	21	19	1,295
Pink	180	None	90	54	25	11	1,493
Gold	200	None	92	44	35	13	1,253
White	220	IB	87	19	23	15	1,433
Pink	180	IB	95	55	31	9	1,281
Gold	200	IB	88	49	24	15	1,231
Weigela floribunda—Jun 21 to Jul 15							
White	220	IB	86	65	15	6	—
Pink	180	IB	82	61	8	13	—
Gold	200	IB	64	42	10	12	—
Buddleia davidii Franch—Jun 28 to Jul 15							
White	220	None	73	36	12	25	—
Soft white	210	None	78	34	21	23	—
Blue and pink	190	None	17*	8	11	28	—
Ligustrum ovalifolium Jun 28 to Aug 8 (50 Cuttings Per Treatment)							
White	220	None	31	13	6	12	—
Soft white	210	None	43	18	11	14	—
Blue and pink	190	None	25	8	6	11	—

*Indicates significant mean difference (5 per cent probability) in comparison with white.
**Indicates highly significant mean difference (1 per cent probability)

deserves mention, and may suggest some sort of inhibitory action of blue light on rooting.

The results of these trials are in harmony with the principle established previously that the orange-red end of the spectrum is more important in the rooting of cuttings than the blue end. These tests also prove that none of the colors of hot cathode lamps available has any definite advantage over the 3500-degree white lamps with respect to the rooting of cuttings.

ROOTING OF CUTTINGS UNDER COLD CATHODE LIGHTING

Cold cathode lighting offers some promising unexploited opportunities in plant experimentation. The range of colors available through the use of different gases, phosphors, and tinted glass tubes is large. The tubes are instant-starting and may be used in rapid flashing operation, and within certain limits, dimming is possible. The deterioration of the tubes or change in spectral quality is very slow in this type of tube. According to Chanon and Barr (1) the efficiency compares favorably with that of hot cathode fluorescent lamps, if tubes at least 5 to 8 feet long are used to minimize electrode losses. The cold cathode tubes also have a much greater length of life. Little auxiliary equipment is necessary for series operation, but amateur experimentation with equipment and circuits of this type should be discouraged because of the high voltages required. Low voltage cold cathode tubes are now obtainable, but were not used in these experiments because of the limited range of colors available at present. This development holds much promise for the future.

Efficiency in operation was sacrificed to some extent in these experiments for convenience and flexibility in experimentation. Cold cathode tubes 42 inches in length from center to center of the terminal electrodes were made in a local neon sign shop. The electrodes were mounted at right angles to the tubes for placement in porcelain twin housings. High voltage cable was used for the necessary wiring. Clear glass was used for the helium-filled tubes. Clear glass neon and also glass tubes coated with two different phosphors were used with neon. All of the tubes containing argon with mercury had fluorescent coatings. Eighteen mm. tubes were used in all cases except with those filled with helium, which were 13 mm. The gas pressure in the tubes was 6 mm. of mercury in all cases except with helium, which was 4 mm.

COLD CATHODE LIGHTING IN A MINIATURE PROPAGATING CASE

Cold cathode lighting was used with good results for rooting of cuttings in a cabinet of Masonite about 4 feet long and 2 feet wide. Two parallel 42-inch tubes were used with a small 4000 volt, 18 milliampere transformer. In this unit, bottom heat was provided by a 50 watt carbon filament lamp or a socket heater of the sealed type, which heated an air space beneath the removable metal flats in which the cuttings were placed. The cuttings received about 80 foot candles from the two tubes which were placed about 9 inches above them. Scarcely any heat was detectible by the hand, when placed on the tubes. The low light intensities would not, of course, permit this case to be used for the starting of seedlings. The rooting medium was usually kept at about 70 degrees F.

The rooting of cuttings obtained was invariably outstanding. Remarkably heavy rooting of azaleas was obtained in a rooting medium of two parts of peat and one part of vermiculite. Excellent rooting was also obtained in shredded sphagnum or in peat alone, if watered sparingly. Cuttings of *Cinchona* placed in flats of shredded sphagnum, washed flue ash, and in vermiculite were rooted heavily in one month under continuous illumination. During this period, the cuttings in the sphagnum and in the flue ash received no watering or other attention. The cuttings in vermiculite were watered only once, but probably this was unnecessary. In this system of propagation, the amount of attention required can be so little that systems of automatic watering may have a doubtful usefulness.

Cold Cathode Lighting in a Semi-Underground Shed

The cutting bench on one side of the semi-underground shed previously described was illuminated by cold cathode tubes. Three parallel tubes, 10 inches apart, supplied the light for each section. The colors were separated by barriers of composition board. Six colors could be compared simultaneously. The electrical system consisted of a 15,000 volt, 30 milliampere transformer operating on the 110 volt lighting circuit, which operated 63 feet of tubes. Usually about 21 feet of these were neon filled. Because of their high resistance, when helium filled tubes were included, one third of the tubes were eliminated from the trials. Neon filled tubes also have a somewhat higher resistance than those filled with argon-mercury.

Effect of Color of Light on Rooting of Cuttings

Since the equipment for cold cathode lighting is not well standardized at the present time and since published information on their spectral distributions is not available, the cold cathode tubes were never used in direct comparisons with hot cathode equipment. Moreover, the color quality changes if the tubes are somewhat overloaded and become hot during operation. The phosphors used at present by different manufacturers vary, although progress toward standardization is being made. No spectrographic analysis of the radiation of the various tubes was attempted. These tests were conducted at relatively low levels of illumination. Nevertheless the results obtained under the colors most favorable to rooting were entirely satisfactory and somewhat comparable to those obtainable in conventional greenhouses or frames. The data for these experiments are shown in Table V.

The blue, green, and gold tubes were not promising in the early tests and were soon eliminated. The 3500-degree white tubes were used as controls as in the previous tests with hot cathode fluorescent lamps. However, the white cold cathode tubes did not have any consistent superiority over the daylight tubes. This unexpected discrepancy in results is possibly explained by the somewhat higher light readings from the daylight tubes used in these experiments. This may have been due to some peculiarity in their manufacture.

As was shown previously, no color of cold cathode fluorescent tube produced rooting which was superior to that obtainable from 3500-degree white tubes. However, with the cold cathode tubes, the results with the two fluorescent neons, rose and orange, were almost invariably superior to those obtainable with either white or daylight tubes, in spite of the somewhat lower efficiency of the neon tubes. The rooting of cuttings under non-fluorescent neon tubes of clear glass was somewhat variable and sufficient data have not been accumulated to evaluate the results with certainty. However, the fluorescent neon tubes appeared to be superior to neon tubes of clear glass.

A number of observations on cuttings under the fluorescent neon

TABLE V—Rooting of Cuttings Under Cold Cathode Tubes

Color of Light	Intensity in Foot Candles	Treatment With Growth Substance	Number of Cuttings Rooted				Total Root Weight (Mg)
			Total	Heavy	Medium	Light	
Forsythia intermedia var. densiflora—May 2 to May 17 (40 Cuttings Per Treatment)							
White	45	None	31	14	5	12	—
Daylight.....	55	None	35	15	12	8	—
Green...... .	30	None	29	4	6	19	—
Rose... .	40	None	33	14	6	13	—
White	45	IB	39	19	9	11	—
Daylight ..	55	IB	36	20	5	11	—
Green. . . .	30	IB	27	4	4	19	—
Rose .	40	IB	39	28	7	4	—
Weigela floribunda—May 26 to Jun 17 (100 Cuttings Per Treatment)							
White	45	None	53	20	14	19	—
Daylight....	55	None	45	16	10	19	—
Rose....	40	None	68	28	14	26	—
Gold	40	None	47	3	12	32	—
Blue .	50	None	23*	—	7	16	-
Ligustrum ovalifolium—Jun 19 to Jul 30 (100 Cuttings Per Treatment)							
White.......	45	None	16	—	5	11	44
Daylight	55	None	26	—	10	16	84
Rose	40	None	59**	28	7	24	359**
Orange ..	40	None	55**	29	13	13	308**
Ruby..	10	None	0	--	--	-	—
White.	45	IB	52	18	8	26	203
Daylight .. .	55	IB	46	—	23	23	219
Rose..	40	IB	77**	41	15	18	521**
Orange . .	40	IB	73**	35	25	13	517**
Ruby. .	10	IB	12**	—	4	8	26**
Salvia splendens Ker-Gawl.—July 31 to Aug 13 (50 Cuttings Per Treatment)							
White . .	45	None	48	3	38	7	170
Daylight ..	55	None	50	29	17	4	260*
Rose	40	None	50	28	20	2	239
Orange... ..	40	None	50	29	19	2	260*
Ruby	10	None	37*	—	8	29	17**
Pachysandra terminalis Michx.—Aug 17 to Sep 20 (50 Cuttings Per Treatment)							
White.	45	IB	50	25	13	12	498
Daylight....	55	IB	47	29	12	6	574
Rose	40	IB	45	22	14	9	678*
Orange	40	IB	48	33	9	6	648*
Helium......	10	IB	46	17	15	14	256**
Cinchona succirubra—Sep 27 to Oct 31 (50 Cuttings Per Treatment)							
White..... .	45	None	48	15	21	12	—
Daylight.....	55	None	49	12	27	10	—
Rose	49	None	49	17	16	16	—
Orange ...	48	None	48	20	15	13	—
Neon .	46	None	46	4	18	24	—

*Indicates significant mean difference (5 per cent) in comparison with white.
**Indicates highly significant mean difference (1 per cent)in comparison with white.

tubes also deserve mention. If relatively soft or immature cuttings were placed under these colors, the cuttings became turgid and erect long before they did under any of the argon-mercury tubes. Also after a few weeks under fluorescent neon tubes, cuttings could be distinguished from those under other tubes by touch alone because of their firmer, more leathery character. Cuttings under these tubes often had a particularly healthy appearance. However, cuttings held for long periods of time under neon tubes of both types have shown some abnormalities. Thus cuttings of *Cinchona succirubra* held for 3 months after heavy rooting had taken place had many leaves with completely twisted petioles and the leaves showed some bronzing of the foliage together with a slightly chlorotic appearance of the vein-clearing type. These cuttings became normal after a relatively short period of exposure to light from blue cold cathode tubes.

The importance of light from certain definite regions of the spectrum is shown by the behavior of cuttings under ruby (fluorescent) and helium (clear glass) tubes. Both of these produced only about 10 foot candles on the cuttings. Cuttings rarely rooted under the ruby root and could not be maintained in good condition. Potted seedlings under this light died quickly. However, under the helium tubes, which produce light of a salmon pink color, moderate rooting of cuttings was obtained in about the normal period of time. A fact which may have some significance is that one of the lines in the radiation emitted by helium is very close to the peak band of absorption by chlorophyll in the red end of the spectrum.

Starting Seedlings Under Fluorescent Lamps

The production of good seedlings under fluorescent lamps requires considerably higher light intensities than are needed for the rooting of cuttings, but does not involve any unusual difficulties. From 600 to 800 foot candles should be sufficient to produce excellent seedlings of the sun-loving annual vegetable and flowering plants, although good seedlings of some shade-loving species have been grown at less than half this intensity. Light intensities of about 800 foot candles prevail immediately beneath the two tubes of a double 40-watt fixture with reflector and diminish to about 450 foot candles at one foot from the tubes.

With two or four tubes in use, the highest quality of seedlings resulted from raising the seed pans or flats to within a few inches of the lamps. However, the area within 1 foot of the tubes was usable with good results, except at the ends, where the light production of the tubes in current use is somewhat low.

Severance (9) has shown that the correct design of reflectors for fluorescent lamps is a complex problem. Types for efficient light distribution at this close range have not been developed adequately.

Satisfactory growth of seedlings can be obtained only under a reasonably well balanced light, containing sufficient radiation in the blue-violet end of the spectrum to produce a firm, short jointed growth. Since the objective is not entirely the maximum growth rate, but also the ability of the seedlings to transplant well, the combination of lamps which will approach this ideal most closely cannot be determined until extensive field transplanting tests have been completed.

Hamner (3) reported that a mixture of white and daylight tubes was most satisfactory for growing plants to maturity under fluorescent lamps as a sole light source. This combination produced excellent seedlings of normal appearance in the present experiments. The character of the growth produced was influenced considerably by the balance of radiation in the blue and the red ends of the spectrum. Thus the 3500-degree white tubes when used alone produced a rapid but somewhat soft growth because of the relatively high proportion of red light. The soft white tubes have somewhat more blue and produce a rapid, but reasonably firm type of growth. Combinations of blue with 3500-degree white tubes produced excellent seedlings, although the most favorable proportion has not been determined. Daylight tubes alone produce a somewhat slow, but well hardened growth. Thus by using various colors alone or in combinations, the character of the seedlings can be influenced considerably.

Temperature is a critical factor in the production of good seedlings under artificial light. The air temperatures must be kept down to a reasonable level so that the light requirements of the seedlings are not increased beyond the available illumination. Lauritzen, Brandes and Matz (5) found in varying temperatures for sugar cane that at each level there was a minimum light intensity for mere survival, and also for health and growth. The light requirements increased as the temperature was raised.

Although the optimal temperatures for seedlings vary considerably from species to species, apparently compromises can be made which permit reasonably good development of seedlings of some cool season and warm season crops when grown together.

Under the more favorable colors or combinations of colors mentioned above, seedlings of various types of plants have been excellent in quality. Thus seeds of cabbage, kale, head lettuce, pansies, stocks and wallflowers were sown in the large opaque propagating house under double 40 watt fixtures, using sphagnum moss in accordance with the directions given by Stoutemyer, Close and Hope (11). The temperatures fluctuated, but were usually slightly above 60 degrees F. The plants of lettuce were slightly etiolated, and doubtless would have been better under lower temperatures, but the other species showed close to normal development. In 5 weeks, the cabbage plants were 3 to 4 inches high, having two large leaves and one or two smaller. The pansy plants were one and one-half inches high and had from three to five leaves. The plants of stocks and wallflowers were 1 inch high with four to eight true leaves. Seeds of cucumber germinated irregularly at this temperature, but the plants grew excellently, and were short-jointed, with large, firm leaves. Tomato, snapdragon, petunia, zinnia, marigold, and sweet pepper germinated well and often made a surprisingly rapid growth, even when nutrients were not applied to the sphagnum moss. These seed pans were held close to the tubes at first, but were lowered as the seedlings elongated. In all stages of germination and growth these seedlings did not differ in any noticeable way from seedlings started and grown in the greenhouse.

SUMMARY

Opaque structures are practicable for various operations in propagation. They aid in eliminating difficulties arising from fluctuations in temperature and humidity. The exact control of light quality, intensity, and period of illumination is made possible.

Radiation in the orange-red end of the spectrum favors rooting of cuttings. Satisfactory rooting can be obtained under relatively low light intensities, but much more light is required for starting seedlings. A certain amount of blue light is necessary for the production of short, stocky seedlings.

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Tables of Coefficients for Estimating Oblate and Prolate Spheroidal Surfaces and Volumes from Spherical Surfaces and Volumes[1]. For Finding Fruit Surfaces and Volumes

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INTRODUCTION

FRUITS and nuts are often spheroidal in shape, being either flattened at the poles (oblate spheroidal) or elongated at the poles (prolate spheroidal). Different types of work in agricultural research and engineering frequently require measurements of surfaces or volumes of oblate and prolate spheroids. This has been demonstrated in the work of various investigators requiring such measurements as surfaces of oranges (1, 24, 25, 26), apples, pears, and plums (2), and of walnuts (7); volumes of muskmelons (4); volume changes in growth of cucurbits (22); molecular shapes and diffusion rate (9, 12, 17); gravitational attraction (19); diffraction of waves by ribbons and by sheets (11); and electrical oscillations of a prolate spheroid (14, 15, 16). Numerous other applications of spheroidal wave functions outside the field of biology are listed by Stratton, Morse, Chu, and Hutner (23).

It seems probable that tables of surfaces and volumes of oblate and prolate spheroids will be found useful in studies on respiration, transpiration, radiation, heat transfer, catalysis (enzymes), colloids, soil particles, storage and packing space. They may also prove useful in studies on insecticidal and fungicidal sprays of fruits such as apples, avocados, blackberries, cantaloupe, chestnuts, cranberries, dates, eggplant, figs, gooseberries, grapefruit, grapes, lemons, melons, oranges, peaches, pears, pecans, plums, raspberries, squash, tomatoes, walnuts, watermelons, of rootcrops such as onions, radishes, and turnips, and of leafy produce such as cabbages; and also in studies on such miscellaneous items as eggs of insects and hens, cell nuclei, pollen grains, cellulose particles, et cetera, by direct use of the tables, or application of two or more tables or certain modifications of them.

The calculation or measurement of surfaces of fruits and other objects of the above shapes is particularly time-consuming. With this in mind, tables of numerical values of surfaces and volumes of oblate and prolate spheroids were prepared by Turrell (24). In these tables the surface and volume values of prolate and oblate spheroids and spheres are given for ranges of axis sizes and spheroidal shapes corresponding to those found in citrus fruits. While appropriate selection of a unit of measure adapts the tables to sizes ranging from millimicrons to kilometers, as required, it is conceivable that the shape range, that is, the eccentricity, might not adequately cover all requirements. The tables included here meet this requirement and have the advantage of brevity. They are of value where a few computations of not more than three significant figures are desired. Volume calculation, also, though relatively easy, is greatly simplified by the use of the tables of coefficients.

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[1] Paper No. 542, University of California Citrus Experiment Station, Riverside, California.

[2] The authors wish to express their appreciation to the Texas Gulf Sulphur Company for a grant in aid for a portion of this work, and to Miss Patricia Hamblin for making the chart for Fig. 2.

METHODS

Calculation of Surfaces and Volumes of Spheres:—Surfaces (S) and volumes (V) of spheres may be calculated from the formulae $S = 4\pi r^2$, and $V = \frac{4}{3}\pi r^3$, respectively, where r is the radius. Surfaces and volumes corresponding to diameters by fractions may be found in Table 21 of Perry's handbook (18), or in *Machinery's Handbook* (13). Volumes corresponding to diameters by hundredths may be found in Table 22 of Perry's handbook (18), and surfaces and volumes corresponding to diameters by tenths may be found in Turrell's tables (24).

Calculation of Surface (σ) Coefficients:—The "σ coefficients" are basically derived from "Proposition 4" of Archimedes (8): "The area of any ellipse is to that of the auxiliary circle as the minor axis to the major". It follows that the surface of an ellipsoid generated by revolution of an ellipse about its major or minor axis is to that of the auxiliary sphere generated by revolution of the auxiliary circle about its axis as a function of the minor axis to the major. Elliptic functions and elliptic integrals (which deal with the problems of the spheroid) appear in such early publications as those of Euler, Legendre, Abel, Jacobi, and Weierstrass, and in the unpublished work of Gauss.

The surfaces (S) of the oblate and prolate spheroids have been obtained from Turrell's tables (24) or have been calculated from formulae commonly derived in integral calculus[3] (21). The formulae as given by Hodgman (10) are:

$$S_{oblate} = 2\pi a^2 + \pi \frac{b^2}{e} \log_E \frac{1+e}{1-e}, \text{ and} \tag{1}$$

$$S_{prolate} = 2\pi b^2 + 2\pi \frac{ab}{e} \sin^{-1} e, \tag{2}$$

where a is the major semiaxis, b the minor semiaxis, and the eccentricity $e = \frac{\sqrt{a^2 - b^2}}{a}$. These formulae are precise for the entire range of eccentricities, as can be determined by the manner of derivation. The derivations are given in part by Byerly (3) and Turrell (24). The "σ coefficients" have been derived from these formulae by dividing the surfaces of the spheroids having major axes ($2a$) of 10.0

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[3] These formulae were kindly derived by Professor G. E. F. Sherwood.

and varying minor axes (2*b*), by the surface of a sphere having a diameter of 10.0 (Fig. 1). The derivations are as follows:

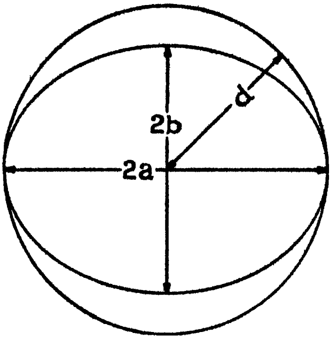

FIG. 1. An ellipse (a section through the center of a prolate spheroid of revolution) with the major axis (2a) equal to the diameter (d) of circumscribed (auxiliary) circle (a section through the center of a sphere of revolution).

$$(3)\qquad \sigma_{oblate} = \frac{\overset{2a\,=\,10.0}{S}_{oblate}}{\overset{d\,=\,10.0}{S}_{sphere}} = \frac{2\pi a^2 + \frac{\pi b^2}{e}\log_E \frac{1+e}{1-e}}{\pi d^2}$$

$$(4)\qquad = \frac{2a^2 + \frac{b^2}{e}\log_E \frac{1+e}{1-e}}{d^2}, \text{ and}$$

$$(5)\qquad \sigma_{prolate} = \frac{\overset{2a\,=\,10.0}{S}_{prolate}}{\overset{d\,=\,10.0}{S}_{sphere}} = \frac{2\pi b^2 + 2\pi\frac{ab}{e}\sin^{-1}e}{\pi d^2}$$

$$(6)\qquad = \frac{2b^2 + \frac{2ab}{e}\sin^{-1}e}{d^2}.$$

According to Sherwood equation 4 in terms of ρ where

$\rho = \frac{b}{a} = \sqrt{1-e^2}$ is

$$\frac{3}{2a}\left(1 + \frac{\rho}{\sqrt{1-\rho^2}}\log_E \frac{1+\sqrt{1-\rho^2}}{\rho}\right), \text{ and}$$

equation 5 is

$$\frac{3\rho}{2a}\left(\rho + \frac{\sin^{-1}\sqrt{1-\rho^2}}{\sqrt{1-\rho^2}}\right).$$

The "σ coefficients" for various spheroids have been determined for ratios (ρ) of $\frac{\text{minor axis } (2b)}{\text{major axis } (2a)}$ at intervals of 0.01, and range from 0.00 to 0.99. The values of ρ form the arguments of the tables. The coefficients (σ) which constitute the functions in the tables, when multiplied by the surfaces of spheres having diameters equal to the major axes of the spheroids, will yield the surface of the required spheroid.

Calculation of Volume (v) *Coefficients:*—The volumes (V) have been obtained from Turrell's tables (24), or have been calculated from formulae commonly derived in integral calculus (21). The formulae as given by Hodgman (10) are:

$$V_{oblate} = \frac{4}{3}\pi a^2 b, \text{ and} \tag{7}$$

$$V_{prolate} = \frac{4}{3}\pi a b^2, \tag{8}$$

where a is the major semiaxis and b the minor semiaxis. These formulae are also precise for the entire range of eccentricities. The "v coefficients" have been derived from these formulae by dividing the volumes of the spheroids having major axes ($2a$) of 10.0 and varying minor axes ($2b$), by the volume of a sphere having a diameter of 10.0. The derivations of the "v coefficients" are as follows:

$$v_{oblate} = \frac{\overset{2a\,=\,10.0}{V}_{oblate}}{\overset{d\,=\,10.0}{V}_{sphere}} = \frac{\frac{4}{3}\pi a^2 b}{\frac{4}{3}\pi r^3} = \frac{a^2 b}{r^3} = \frac{b}{r} = \frac{b}{a}, \text{ and} \tag{9}$$

$$v_{prolate} = \frac{\overset{2a\,=\,10.0}{V}_{prolate}}{\overset{d\,=\,10.0}{V}_{sphere}} = \frac{\frac{4}{3}\pi a b^2}{\frac{4}{3}\pi r^3} = \frac{b^2}{r^2}. \tag{10}$$

The "v coefficients" for various spheroids have been determined for the same values of ρ as the "σ coefficients". The coefficients (v) which constitute the functions in the tables, when multiplied by the volumes of spheres having diameters equal to the major axes of the spheroids, will yield the volume of the required spheroid.

Checking of Coefficients:—The numerical values for surfaces and volumes of the oblate and prolate spheroids, prior to calculation of the coefficients, were checked according to the method used in the numerical tables (24). After the coefficients were calculated, these were plotted against ρ on a large scale. Irregular points in the curves were checked for the degree of error. If this exceeded the probable error, complete recalculation of the coefficient was made.

At the lower limits, surfaces and volumes of disks, cylinders, and cones were calculated and compared with the surface and volume calculations of the spheroids.

Recalculations of several values of each table have been made independently by two investigators. Also, various hypothetical problems have been solved and checked with the numerical tables (24).

USE OF THE COEFFICIENT TABLES

Surface Estimation: A fruit measuring 8.2 cm from stem to stylar end (polar axis), and measuring 7.6 cm at right angles to this (equatorial axis), is extended in the polar dimension and is called "prolate." The ratio $\rho = \frac{2b}{2a} = \frac{7.6}{8.2} = 0.927$, or (rounded) 0.93, is found on the sides of the table—0.9 on the vertical axis and 0.03 on the horizontal axis. The "σ coefficient" is 0.908. The surface (S) of a sphere may be calculated by using the formula $S = \pi d^2$, where d is the diameter, or may be obtained from tables of Perry (18) or Turrell (24). A sphere with a diameter of 8.2 cm has a surface of 211 cm². The fruit surface then will be $S^{2a=d}_{spheroid} = \sigma S^{2a=d}_{sphere}$, and substituting the numerical values in the equation, the surface of the spheroid will be 211 × 0.908 = 191.59, or 192 cm².

A higher degree of accuracy may be obtained by simple linear interpolation. $\rho = 0.927$; thus the proper "σ coefficient" has a value greater than that for 0.920 by 0.7 of the difference between those for 0.930 and 0.920. Where $\rho = 0.920$, $\sigma_1 = 0.895$; and where $\rho = 0.930$, $\sigma_2 = 0.908$.

$$\sigma_2 - \sigma_1 = 0.908 - 0.895 = 0.013$$
$$\sigma_1 + 0.7\,(\sigma_2 - \sigma_1) = 0.895 + 0.7 \times 0.013 = 0.904$$
$$S_{prolate} = S_{sphere} \times \sigma = 211 \times 0.904 = 190.74.$$

Thus the surface of the fruit would be 191 cm².

Volume Estimation:—If it is assumed that a fruit has the same measurements as the fruit used for the surface estimations above (*i.e.*, $2a = 8.2$ cm and $2b = 7.6$ cm), but that the polar axis is the shorter and the equatorial axis the longer, then the fruit is oblate in shape (compressed in the polar dimension). The ratio $\rho = \frac{2b}{2a} = \frac{7.6}{8.2} = 0.927$, or 0.93, as above, is found on the sides of the table—0.9 on the vertical axis and 0.03 on the horizontal axis. The "υ coefficient" corresponding to this value of ρ is 0.930. The volume (V) of a sphere may be calculated for $d = 2a = 8.2$, using the usual formula, or may be obtained from the tables (18, 24). The volume of such a sphere is 289 cm³. The fruit volume then will be

$$V^{2a=d}_{spheroid} = \upsilon V^{2a=d}_{sphere},$$

and substituting the numerical values in the equation, the volume of the spheroid will be 289 × 0.930 = 268.77. Thus the volume of the fruit would be 269 cm³. A more previse value may be obtained by interpolation, as shown for surface.

RESULTS

Coefficients for finding the surfaces and volumes of oblate and prolate spheroids from the surfaces and volumes of spheres having diameters equal to the major axes of the spheroids are given in Tables I, II, III, and IV.

TABLE I—COEFFICIENTS (σ) FOR DETERMINING THE SURFACES OF OBLATE SPHEROIDS FROM THE SURFACES OF SPHERES HAVING DIAMETERS EQUAL TO THE MAJOR AXES OF SPHEROIDS, THE AXES RATIOS OF WHICH ARE INDICATED AT TOP AND SIDE OF TABLE BY ρ. $\rho = \frac{2b}{2a}$.

ρ	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5003	0.5009	0.5019	0.5031	0.5046	0.5063	0.5082	0.5103	0.5125
0.1	0.515	0.518	0.520	0.523	0.526	0.529	0.533	0.536	0.539	0.543
0.2	0.517	0.551	0.554	0.558	0.562	0.567	0.571	0.575	0.579	0.584
0.3	0.588	0.593	0.598	0.602	0.607	0.612	0.617	0.622	0.627	0.632
0.4	0.637	0.642	0.647	0.652	0.658	0.663	0.668	0.674	0.679	0.685
0.5	0.690	0.696	0.701	0.707	0.712	0.718	0.724	0.730	0.736	0.741
0.6	0.747	0.753	0.759	0.765	0.771	0.777	0.783	0.789	0.795	0.801
0.7	0.807	0.813	0.820	0.826	0.832	0.838	0.844	0.851	0.857	0.863
0.8	0.870	0.876	0.882	0.889	0.895	0.902	0.908	0.915	0.921	0.928
0.9	0.934	0.941	0.947	0.954	0.960	0.967	0.973	0.980	0.987	0.993

TABLE II—COEFFICIENTS (σ) FOR DETERMINING THE SURFACES OF PROLATE SPHEROIDS FROM THE SURFACES OF SPHERES HAVING DIAMETERS EQUAL TO THE MAJOR AXES OF SPHEROIDS, THE AXES RATIOS OF WHICH ARE INDICATED AT TOP AND SIDE OF TABLE BY ρ. $\rho = \frac{2b}{2a}$.

ρ	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.00000	0.00788	0.01582	0.02375	0.03131	0.04011	0.04842	0.05514	0.06303	0.07094
0.1	0.0790	0.0869	0.0949	0.103	0.111	0.119	0.127	0.135	0.143	0.152
0.2	0.160	0.168	0.176	0.185	0.193	0.201	0.210	0.218	0.227	0.235
0.3	0.244	0.253	0.261	0.270	0.279	0.288	0.297	0.306	0.315	0.325
0.4	0.334	0.341	0.350	0.360	0.369	0.379	0.389	0.398	0.408	0.417
0.5	0.427	0.436	0.446	0.455	0.468	0.478	0.487	0.497	0.506	0.516
0.6	0.529	0.538	0.548	0.561	0.570	0.580	0.592	0.602	0.611	0.624
0.7	0.634	0.646	0.656	0.669	0.678	0.691	0.704	0.713	0.726	0.739
0.8	0.748	0.761	0.774	0.783	0.796	0.809	0.823	0.834	0.847	0.857
0.9	0.869	0.882	0.895	0.908	0.920	0.933	0.946	0.962	0.975	0.987

TABLE III—COEFFICIENTS (v) FOR DETERMINING THE VOLUMES OF OBLATE SPHEROIDS FROM THE VOLUMES OF SPHERES HAVING DIAMETERS EQUAL TO THE MAJOR AXES OF SPHEROIDS, THE AXES RATIOS OF WHICH ARE INDICATED AT TOP AND SIDE OF TABLES BY ρ. $\rho = \frac{2b}{2a}$.

ρ	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.000	0.010	0.020	0.030	0.040	0.050	0.060	0.070	0.080	0.090
0.1	0.100	0.110	0.120	0.130	0.140	0.150	0.160	0.170	0.180	0.190
0.2	0.200	0.210	0.220	0.230	0.240	0.250	0.260	0.270	0.280	0.290
0.3	0.300	0.310	0.320	0.330	0.340	0.350	0.360	0.370	0.380	0.390
0.4	0.400	0.410	0.420	0.430	0.440	0.450	0.460	0.470	0.480	0.490
0.5	0.500	0.510	0.520	0.530	0.540	0.550	0.560	0.570	0.580	0.590
0.6	0.600	0.610	0.620	0.630	0.640	0.650	0.660	0.670	0.680	0.690
0.7	0.700	0.710	0.720	0.730	0.740	0.750	0.760	0.770	0.780	0.790
0.8	0.800	0.810	0.820	0.830	0.840	0.850	0.860	0.870	0.880	0.890
0.9	0.900	0.910	0.920	0.930	0.940	0.950	0.960	0.970	0.980	0.990

TABLE IV—COEFFICIENTS (v) FOR DETERMINING THE VOLUMES OF PROLATE SPHEROIDS FROM THE VOLUMES OF SPHERES HAVING DIAMETERS EQUAL TO THE MAJOR AXES OF SPHEROIDS, THE AXES RATIOS OF WHICH ARE INDICATED AT TOP AND SIDE OF TABLE BY ρ. $\rho = \frac{2b}{2a}$.

ρ	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0001	0.0004	0.0009	0.0016	0.0025	0.0036	0.0049	0.0064	0.0081
0.1	0.0100	0.0121	0.0144	0.0169	0.0196	0.0225	0.0256	0.0289	0.0324	0.0361
0.2	0.0400	0.0441	0.0484	0.0529	0.0576	0.0625	0.0676	0.0729	0.0784	0.0841
0.3	0.0900	0.0961	0.102	0.109	0.116	0.123	0.130	0.137	0.144	0.152
0.4	0.160	0.168	0.176	0.185	0.194	0.203	0.212	0.221	0.230	0.240
0.5	0.250	0.260	0.270	0.281	0.292	0.303	0.314	0.325	0.336	0.348
0.6	0.360	0.372	0.384	0.397	0.410	0.423	0.436	0.449	0.462	0.476
0.7	0.490	0.504	0.518	0.533	0.548	0.563	0.578	0.593	0.608	0.624
0.8	0.640	0.656	0.672	0.689	0.706	0.723	0.740	0.757	0.774	0.792
0.9	0.810	0.828	0.846	0.865	0.884	0.903	0.922	0.941	0.960	0.980

DISCUSSION

Errors in Application of Tables:—As has been pointed out previously, the formulae used for calculating the surfaces and volumes of the oblate and prolate spheroids are precise for perfectly shaped bodies, their precision as used here being primarily dependent on the number of significant figures. The elimination of π from the formulae for calculating the σ and v coefficients eliminates the effects of the number of decimal places carried in π. Thus in the surface calculations the precision of the formulae depends on the number of places used in the arguments of the $\sin^{-1}x$ tables and $\log_E$ tables. The arguments in the $\sin^{-1}x$ tables used had three significant figures (5), and this has limited the number of significant figures for the "σ coefficients" to three, except in the few cases where it was necessary to carry four significant figures, as in the range of $\rho = 0.00$ to $\rho = 0.09$. Although the $\log_E$ tables used (6) had 16 places in the functions, only enough figures were retained to give accuracy equivalent to the functions given in the $\sin^{-1}x$ tables.

The precision of the formulae for the volume coefficients, as can be ascertained from formulae 9 and 10, depends upon the number of significant figures carried. In the case of the "v coefficients" for oblate spheroids, only three figures have been carried; but since ρ and the "v coefficients" are equivalent, as can be seen in formula 9, any number of places may be obtained by carrying out the division of $\frac{2b}{2a}$. Although only three significant figures have been carried in the "v coefficients" of the prolate spheroids, any degree of precision can be obtained, as shown in Formula 10, by carrying out the division of $\frac{b^2}{r^2}$. Of course, it is unnecessary to have more significant figures for the surface or volume of a spheroid than obtained in the measurement of $2a$ or $2b$.

All the third significant figures in the σ and v coefficients have been obtained by rounding the fourth significant figure. If the fourth significant figure was five or larger, the third significant figure was raised one unit, regardless of whether the number was even or odd; if the fourth significant figure was four or smaller, it was dropped.

The effect of rounding on the per cent error of the coefficients is shown in Table V. It is important for anyone expecting to use the coefficient tables to study the magnitude of the per cent errors

TABLE V—PER CENT ERRORS CAUSED BY ROUNDING

Error Calculated on Function of Magnitude*	Last Figure of Functions	Third Figure of Ratios of Axes Measurements to Fit Two-Place Table Arguments	Fourth Figure of Ratios of Axes Measurements to Fit Third Place of Interpolated Arguments**
		Oblate Surface	
Minimum	0.009995	0.05993	0.005999
Maximum	0.05038	0.3030	0.03039
		Prolate Surface	
Minimum	0.06349	33.50	4.796
Maximum	0.05068	0.6116	0.06150
		Oblate Volume	
Minimum	0.0000	33.33	4.762
Maximum	0.0000	0.5076	0.05099
		Prolate Volume	
Minimum	100.0	60.00	18.0
Maximum	0.5128	1.031	0.1041

*Errors are calculated on minimum values of functions (coefficients) for next to smallest entries in tables, and on maximum values of functions for next to largest entries.

**Using linear interpolation, with degree of curvature for values in interval between coefficients excluded from consideration.

given in Table V, especially if the coefficients are to be employed without interpolation. As shown in the second column of Table V, the errors in the coefficients (functions) are usually insignificant, owing to rounding of the third significant figure, and, in some cases where the coefficient values are near the minimum, owing even to rounding of the fourth significant figure. In one case, however (*i.e.*, for minimum value of v for prolate spheroids), the per cent error is extremely large.

If axes measurements are made to three significant figures, the relative (per cent) errors introduced for the maximum and minimum coefficient values, when the ratios of axes measurements are rounded to two significant figures to fit the arguments (ρ) of the table, are shown in the third column of Table V. These errors are usually quite large when the coefficients of small value are used, but may not be troublesome when use is made of the coefficients of medium or large value.

However, as indicated by the relatively small per cent errors shown in the fourth column of Table V, interpolation is advisable when precision is necessary. The errors discussed have been based on linear interpolation for the interval between successive argument and corresponding function values. Scarborough (20) should be consulted for more precise methods of interpolation. Inspection of Fig. 2 shows that such interpolation is precise throughout the range of oblate volume coefficients (next to uppermost curve), is fairly precise throughout the range of prolate surface coefficients (next to lowermost curve), is fairly precise only for the upper two thirds of the range of prolate volume coefficients (lowermost curve) and oblate surface coefficients (uppermost curve). The per cent errors calculated for oblate surface and prolate volume are therefore to be accepted with some reservation.

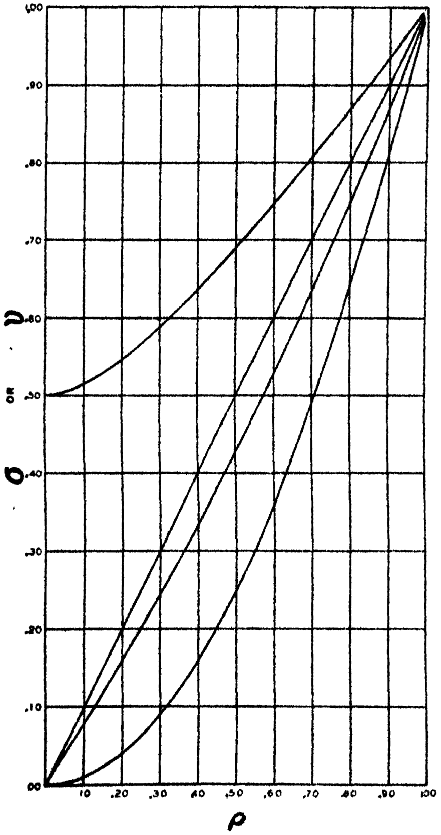

FIG. 2. Curves showing the relationships between σ and ρ for oblate spheroids (uppermost) and for prolate spheroids (next to lowermost), and between υ and ρ for oblate spheroids (next to uppermost) and for prolate spheroids (lowermost).

Since

$$S_{sphere} = \pi d^2,$$

and

$$V_{sphere} = \frac{4}{3} \pi r^3,$$

the errors in these calculations will depend upon the number of significant figures carried in π or $\frac{4}{3}\pi$, and in d or r. These errors may be additive. When the surface or volume coefficients are multiplied by the surfaces or volumes of spheres, the errors in the sphere calculations may be additive to those inherent in the coefficients. There is greater likelihood, however, that there will be some compensation of errors owing to errors different in sign.

Fruits are seldom perfectly shaped spheroids. In using the tables of coefficients to find the surface or volume of fruits from measurements of their major and minor axes, errors occur because of the imperfections of the shape of the fruit. Certain kinds of fruit will approximate spheroidal shapes more closely than others. The error arising from this source has been investigated for citrus fruits by Turrell, Carlson, and Klotz (26), for the numerical values given in the tables (24). When interpolation is used in the coefficient tables, the mean errors for citrus fruit should closely approximate those given by Turrell, Carlson, and Klotz (26). These errors ranged from 2.23 to 5.59 per cent for the surfaces of different kinds of citrus fruit, and from 1.95 to 8.35 per cent for the volumes. Tests for ellipticity are given by Currence *et al.* (4).

Characteristics of σ and v Coefficient Tables:—The σ and v coefficient tables can be used to calculate the surfaces or volumes of oblate or prolate spheroids ranging in shape from a double-pointed needle or a thin wafer to a ball ever so slightly compressed. As shown in Fig. 2, when the "σ coefficients" are plotted against varying values of ρ, gently rising curves are obtained, that for oblate spheroids becoming asymptotic at the lower limits. When the "v coefficients" are plotted against varying values of ρ, a straight line results for the oblate spheroids, and a gently rising curve asymptotic at the lower limit is obtained for the prolate spheroids.

The σ and v coefficients may be used with any unit of measure employed in measuring the major and minor axes. This measure, in square units or cubic units, will be the same as that in which the surfaces or volumes of the spheres to which the coefficients are to be applied are expressed.

SUMMARY

Tables of coefficients are presented for rapidly finding the surfaces and volumes of oblate and prolate spheroids, which fruit often resemble in shape. The methods of deriving and using the coefficients for finding fruit surfaces and volumes are discussed, and examples are given. A critical discussion of the errors involved in using the spheroidal coefficients in estimating fruit surfaces is included.

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Correlation of Means and Standard Deviations In Tomato Field Experiments[1]

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WHEN the Analysis of Variance is used in testing the significance of differences, it is theoretically assumed that the variance within groups is constant from group to group, except for fluctuations due to sampling. The values of the means for groups and their standard deviations are supposed to be unrelated. Only when this condition does prevail can comparisons of variance due to error with variance due to other causes have, strictly speaking, the meanings they are supposed to have. Actually in field experiments, an obvious correlation of means and standard deviation sometimes exists. It is commonly recommended for such cases that the logarithms of the original measurements be analyzed instead of the original measurements themselves. The impression that most textbooks on statistics leave, however, is that in most cases there is no variation of standard deviation with mean. Systems of analysis for complex factorial and quasi-factorial experiments seem to disregard any such relationship. It is the purpose of this paper to present data to show how, in a number of tomato field experiments, the mean (m) and the standard deviation (s) are correlated. Some of these are cases where a logarithmic transformation would generally be suggested; most are not.

SOURCE OF DATA

The results included in this report are from the Purdue tomato field experiments listed below. In order to have variability among means to correlate with any variability among standard deviations, experiments were selected in which the highest mean was at least 50 per cent greater than the lowest. Although for this special study we were not able to analyze all our tests where there was such a range, we have included most of them, and we believe the remaining are well represented both with regard to type of experiment and with regard to correlation of mean and standard deviation.

Experiment 1. Tomato variety test at Lafayette, 1944, with 3 varieties and 24 complete blocks.

Experiment 2. Tomato variety test at Lafayette, 1945, with 15 varieties and 5 complete blocks.

Experiment 3. Tomato variety test at Lafayette, 1945, with 4 varieties and 25 complete blocks.

Experiment 4. Field plot technique experiment at Lafayette, 1941. The data used have been presented in Table I of a previous publication by the authors (1). For study here, the figures for rows 1 and 32 in that table were disregarded, and the remaining rows divided into 9 blocks, each 10 plots wide and 4 plots long.

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[1] Journal Article No. 252 of the Purdue University Agricultural Experiment Station.

Experiment 5. Tomato fertilizer experiment at Trafalgar, 1944, with 7 treatments and 4 complete blocks.

Experiment 6. Tomato fertilizer experiment at Trafalgar, 1945, with 9 treatments and 4 complete blocks.

Experiment 7a. Factorial fertilizer experiment at Lafayette, 1943, here considered as a test of the effect of potash on yield, with 10 treatment means each calculated from 25 small plots.

Experiment 7b. Same as 7a, but data studied were quantities of phosphorus pentoxide extracted with 0.1 per cent acetic acid from the soil of plots which had received radically different superphosphate applications.

Experiment 8. Spraying and date of planting experiment at Plainville, 1945, with 6 treatments and 6 complete blocks.

These experiments have been considered to belong to either one of two types according to range of means. Test of the first type include ones in which the highest of the means for at least one criterion of classification is from 1.5 to 9 times as great as the lowest mean for the same classification. Of the second type are the two experiments in which the highest mean for one criterion of classification was 10 or more times as great as the lowest mean.

RESULTS AND DISCUSSION

A summary of correlation calculations and quantitative details regarding the various experiments is presented in Table I. All the r values greater than .9 are significant at the 1 per cent level. Most of the values less than .9 are not significant when considered alone and without reference to the results in other experiments. Calculations on the original figures from experiments of type 2 thus show high correlation of m and s.

In experiment 8, replacing the original weights by their logarithms resulted in data with a small r for treatments but with a high r for blocks. Probably the high correlation among the original figures in the date-of-planting and spraying experiments is attributable to the fact that the two treatments with late planting bore ripe fruit at only three harvests, whereas the other plantings were picked six times. Individual plot yields were very much lower for the late plantings than for the others and did not have a possibility of varying much, in pounds, from their means.

Tests for phosphates in experiment 7b were made by a visual colorimetric method, which involved comparisons with permanent liquid standards representing .2, .5, 1.0, 2.0, and 5.0 parts per million in the extracting solution. On account of the great range in amounts of phosphate extracted, the technician made readings in units equivalent to about 20 to 50 per cent of the nearest standard. For the higher concentrations it was necessary to dilute the original extract at least 10 to 1. Hence it seems apparent why, without transformation, there should be a close relation between size of mean and size of standard deviation.

All experiments of type 1 show much the same degree of correlation. From a statistical standpoint all these experiments are rather simi-

TABLE I—CORRELATION AND REGRESSION COEFFICIENTS FOR MEANS (m) AND STANDARD DEVIATIONS (s)

No. of Experiment	* Type of Experiment	Criterion of Classification for Which Means (m) and Standard Deviations (s) were Studied	Units in which m and s were Expressed	Number of Means and Number of Standard Deviations	r_{ms} (Uncorrected Correlation Coefficient) *	b_{sm} (Regression Coefficient of Standard Deviation on Mean)	Size of Single Plot as Harvested (Sq. Ft.)	Number of Single Plots Combined in Each Estimate of a Mean and a Standard Deviation
Experiments of Type 1†—Calculations on Original Data								
1	Variety	Block	Lbs fruit per plot	24	0.586**	0.143	400	3
2	Variety	Block	Lbs fruit per plot	5	0.450	0.359	400	15
2	Variety	Variety	Lbs fruit per plot	15	0.430	0.539	400	5
3	Variety	Block	Lbs fruit per plot	25	0.387	0.698	400	4
4	Blank	Block	Lbs fruit per plot	9	0.520	1.098	144	40
5	Fertilizer	Treatment	Lbs fruit per plot	7	0.454	0.872	1,960	4
6	Fertilizer	Treatment	Lbs fruit per plot	9	0.526	0.378	1,960	4
7a	Fertilizer	Treatment	Lbs fruit per plot	10	0.527	0.578	81	25
Experiments of Type 2†—Calculations on Original Data								
7b	Fertilizer	Treatment	Lbs P_2O_5 per acre	10	0.926**	2.208	81	25
8	Planting	Treatment	Lbs fruit per plot	6	0.933**	1.099	441	6
8	Planting	Block	Lbs fruit per acre	6	0.998**	1.629	441	6
Experiments of Type 2†—Calculations on Logarithms of Original Data								
7b	Fertilizer	Treatment	Lbs P_2O_5 per acre	10	−.211	−.187	81	25
8	Planting	Treatment	Lbs fruit per plot	6	0.318	0.972	441	6
8	Planting	Block	Lbs fruit per plot	6	0.951**	0.723	441	6

†See text for explanation of classification into types.
*Significant at 5 per cent level.
**Significant at 1 per cent level.

lar. In any one of them, yields are all determined by equal numbers of pickings, figures are weights in pounds per plot, and the range in value of means is from 25 to 50 per cent above and below the grand mean, except for experiment 4 in which the range is much greater. Size of plots and number of plots on which the sub-total means and standard deviations are based seem unimportant from the standpoint of calculating correlation co-efficients. We have, therefore, determined an average corrected value for r for the eight groups of data by the method described in detail by Snedecor (2). This figure is .473. Chi-square calculations show that P was much greater than .99, which fact gives great credibility to the hypothesis that the r values for the eight sets of data belong to a single population. Since the average r is .473 in these experiments, variation in the mean may be said to account for about 22 per cent of the variance among the individual standard deviations. In experiments of type 2, variation in the mean accounts for from 86 to nearly 100 per cent of the variance among standard deviations.

While the existence of lineal correlation of mean and standard deviation has been shown for experiments of the first type as well as for those of the second, the data do not demonstrate clearly the nature of the relationship, except for experiment 8, where m and s are directly proportional. To continue to assume a lineal regression, $s = b_{sm}m + a$, for all the remaining cases is the simplest and most logical step. Graphic representation of each set of figures, except those involving the logarithms of original measurements, tends to indicate such a relationship, or at least does not suggest a curvilinear regression.

Using the usual regression methods, we determined, for each experiment, values of b_{sm}, which are presented in the seventh column of Table I. However, at least for the type 1 experiments these regression coefficients are not sufficiently accurate to be worth much consideration individually. But for original data they are all positive and the majority of them lie within the range of from .5 to 2.0. Further examination of the data when plotted on graph paper shows that in all cases, except that of experiment 3 and probably of experiment 1, the true value of the constant *a* might well be assumed to be zero. In experiment 3, and less noticeably in experiment 1, there is a tendency for the standard deviation to remain comparatively high as the means for blocks decrease greatly. The biological explanation for this phenomenon seems to be that, as the soil became poorer, the yields of the two varieties of the Rutgers type, which were included, decreased more rapidly than did the yields of the varieties of the Baltimore type. Therefore, there was a tendency for the variance to increase as the block means decreased and this tendency partially obscured the opposite tendency. Although experiments 1 and 3 are thus somewhat different from the others, they no doubt represent many tests in which a comparable interaction of block and treatment exists.

In cases where the coefficient of correlation of m and s is no greater than 0.4, it may rarely make a practical difference, from the standpoint of a horticulturist trying to determine the superiority of one treatment over another, whether or not this relationship is disregarded. This may be especially true for comparatively simple analyses. But it is well to keep in mind that the method of Analysis of Variance does not take into account an apparently very common and perhaps almost universal characteristic of yields from field experiments.

SUMMARY

Correlation of means and standard deviations seems to be characteristic of data from eight tomato field experiments studied. In order to have variability among means to correlate with variability among standard deviations, the experiments selected were ones in which the highest mean for one or more criteria of classification was at least 50 per cent greater than the lowest.

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Rapid Determination of Potassium and Sodium in Plant Materials and Soil Extracts by Flame Photometry

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In connection with field experiments on fruit tree nutrition we have found it desirable to analyse large numbers of plant and soil samples for potassium and sodium. These determinations have been made gravimetrically by a highly systematized procedure so that the average time consumed in determining potassium and sodium on a leaf sample is about 35 minutes. However, through flame photometry methods we have reduced the average time for the potassium plus the sodium determination to 8 minutes per sample.

Flame photometry in its simplest form is typified by instruments made by two German firms, Siemans and Zeiss. These two instruments, which were designed for potassium only, are described by Schmitt and Breitweiser (1) who used and tested both instruments. An improved instrument designed to determine both potassium and sodium is described by Barnes, Richardson, Berry, and Hood (2). The use of the flame method of excitation in spectrography was extensively studied by Lundegardh (3). The adaptation of Lundegardh's methods to analyses of biological material is described by Cholak and Hubbard (4).

In our work we used a commercial model Flame Photometer[1] designed after the one described by Barnes *et al.* (2).

In this instrument, solutions containing potassium and sodium under going analysis are sprayed into an air-propane gas flame by means of an atomizer. The heat of the flame causes the potassium and sodium ions to emit light of their characteristic wave lengths. The amount of light so emitted is proportional to the amount of salt entering the flame. Since, through careful regulation of the air and gas pressure on the atomizer and burner, the rate of solution entering the flame may be made constant, the amount of light emitted is proportional to the concentration of salt in the solution undergoing examination.

The instrument has a light filter which selects the wave length of potassium (approximately 7700 Angstroms) from the other light emissions of the flame. The intensity of the light passing through the filter is measured by a suitable phototube, meter, and galvanometer. By comparing the meter reading of the unknown solution with a standard curve constructed from the meter readings of solutions of known concentrations the concentration of the unknown solution can be determined.

A second filter and phototube system which selects and measures the light emissions (approximately 5900 Angstroms) of sodium is also incorporated in the instrument.

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[1] Model 18 Flame Photometer—manufactured by the Perkin Elmer Corporation, Glennbrook, Conn.

Both filter systems use the same meter and galvanometer which can be readily switched into either circuit, but potassium and sodium cannot be determined simultaneously. The galvanometer is a null type and the meter is a dial resistance graduated into 100 divisions. There are also suitable resistances in the circuit for making the galvanometer adjustments referred to later.

After the photometer is properly installed, its operation is very simple. To determine potassium, for example, the machine is calibrated by preparing a series of standard potassium solutions ranging from zero to the maximum concentration expected in the unknown solutions. Distilled water (zero concentration) is then fed into the atomizer and the galvanometer balanced with the meter at zero. Then the most concentrated solution is introduced into the atomizer and the galvanometer again balanced with the meter at the 100 division point. Then intermediate concentrations are introduced into the atomizer and the galvanometer balanced by moving the meter. By plotting the meter reading at the point of balance against the concentration of the solution a standard curve for potassium may be constructed. The meter reading of an unknown solution can then be compared to the standard curve and the potassium concentration of the unknown solution ascertained.

The same procedure is followed in calibrating the instrument for sodium and for determining sodium. When a new solution is inserted, about 40 seconds are required for the previous solution to be removed from the atomizer and for the new solution to be entering the flame properly.

In general, greater accuracy with the photometer is attained with dilute solutions. In our work we used a solution containing 40 ppm potassium (chloride) and 15 ppm sodium (chloride) as our most concentrated standard, and the meter was set to read 100 with this solution. Dilutions of this solution were used to obtain meter readings for the construction of standard curves.

Our analytical procedure with plant material was as follows: One gram of plant material in a silica crucible was ashed for 2½ hours at 600 degrees C by means of electric muffles. The soluble ash was then taken up in 20 cc of water containing ½ cc of concentrated HNO_3, by heating to near boiling on a hot plate. The contents of the crucible were then transferred to a 100 cc volumetric flask, brought to volume, shaken, and filtered through paper. Ten cc of the filtrate was diluted to 100 cc to make the solution used for determining potassium and sodium on the photometer. These diluted solutions were prepared in sets of 36. Normally they contained less than 40 ppm potassium and 15 ppm sodium.

Approximately 30 cc aliquots of the diluted solutions were transferred into 100 cc beakers. The photometer was adjusted for potassium, setting the meter at 100, using the standard which contained 40 ppm potassium and 15 ppm sodium. Then the beaker containing the first ash solution was placed in the photometer and the meter reading noted after 40 seconds. Then the second solution was placed in the photometer and its meter reading noted. When eighteen solutions had been analysed, the standard was again inserted and if necessary the photometer meter readjusted at the 100 point. When all the solutions had been analysed for potassium the photometer was readjusted for sodium using the standard solution as the most concentrated standard. The ash solutions were then analysed for sodium in the same manner as for potassium.

Somewhat greater accuracy can be obtained with the photometer (2) by certain refinements of operations, such as averaging two separate readings on each solution.

We did not find it necessary to incorporate these refinements into our procedure. The potassium and sodium values shown in Fig. 1 were obtained by the routine procedure described above. Departures from this procedure, however, should be made with care as the presence of excess acid or other ions may seriously affect the accuracy.

The general accuracy of the photometric method was checked by analysing the same plant ash solutions for potassium and sodium using the gravimetric chloroplatinate and zinc uranyl acetate methods. A graphic comparison of the results obtained is shown in Fig. 1. In this graph the photometric potassium values seem lower than those obtained by chemical means. Statistical analyses of 50 comparisons show this to be true, the average photometric value being 1.7 per cent less than the chemical value. The standard deviation of the photometric method from the chemical method was found to be 4.8 ± 3.7 per cent.

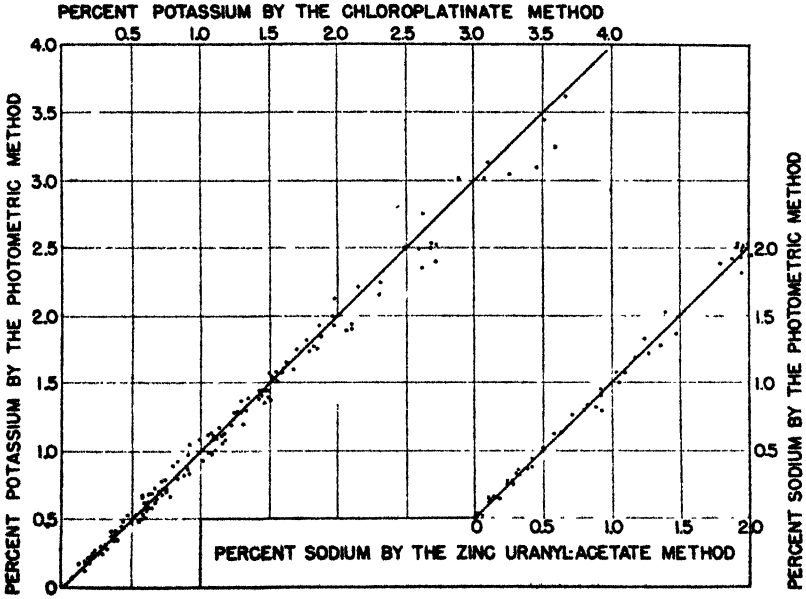

Fig. 1. Comparison between the amount of potassium and sodium found in plant material by the gravimetric chemical method and by the flame photometric method.

Both the photometric and chemical methods as used in our laboratory routine show decreasing accuracy when the sodium in the leaf falls below 0.1 per cent. Since these low amounts of sodium represent normal foliage and growth, we have not attempted to increase accuracy in this range, although we could easily do so by increasing the weight of leaf ashed or by modifying the dilutions.

Omitting sodium values below 0.1 per cent the average photometric values are lower (0.4 per cent) than the average chemical values. The standard deviation of the photometric values from the chemical values was 5.05 ± 3.07 per cent.

As we have indicated, the photometric method is much more rapid than the gravimetric chemical method. By the photometric method the average time required to ash and determine both potassium and sodium on a leaf sample is 8 minutes. The average time required to make the same determination by chemical methods is 35 minutes.

In addition the photometric method does not require the use of expensive platinum and uranium salts. Likewise, the operation of the photometer does not require highly trained personnel.

SOIL ANALYSES

The chemical determination of potassium and sodium in 1–1 water extracts of soil is very time consuming and the results tend to be unreproducible, especially when the amounts of potassium and sodium present are small. These same analyses can be made directly on the extract in a few minutes with the flame photometer.

A comparison of the results obtained by our routine chemical methods and those obtained by the photometer are shown in Table 1. In this case we used our routine colorimetric cobaltinitrite method for potassium and the gravimetric zinc uranyl acetate method for sodium. The photometric analyses were made directly on the untreated extract. Table I shows that the results obtained by the two methods differ con-

TABLE I—COMPARISON OF THE AMOUNTS OF POTASSIUM AND SODIUM FOUND IN 1-1 WATER-SOIL EXTRACTS BY OUR ROUTINE CHEMICAL METHODS AND BY THE PHOTOMETRIC METHOD

Sample Number	Ppm Potassium Found		Ppm Sodium Found	
	By the Chemical Method	By the Photometric Method	By the Chemical Method	By the Photometric Method
1	9.3	9.0	71.0	71.0
2	2.7	1.7	89.0	82.0
3	2.5	2.0	171.0	171.0
4	2.1	1.9	222.0	222.0
5	2.1	2.8	265.0	260.0
6	2.5	2.5	320.0	290.0
7	3.3	2.9	328.0	292.0
8	3.3	2.9	340.0	297.0
9	4.3	4.7	5.0	3.0
10	3.6	3.7	3.0	2.0
11	3.3	3.5	4.0	3.0
12	5.0	3.2	3.0	2.0
13	3.9	4.3	3.0	2.0
14	3.3	1.2	3.0	3.0
15	2.5	0.8	3.0	3.0
16	2.7	1.0	4.0	2.0
17	10.0	10.0	20.0	15.0
18	5.2	4.5	17.0	14.0
19	4.5	2.5	17.0	14.0
20	1.1	0.8	12.0	10.0

siderably. This may be caused by inaccuracy in either or both methods, but since the amounts of potassium and sodium are small we suspect the chemical method to be least accurate as it is less suited for small amounts.

In order to increase the accuracy of the chemical method we prepared large volumes of 1-1 water extracts of soil. We evaporated 500 cc portions to small volume and then determined potassium and sodium gravimetrically by the chloroplatinate and uranyl acetate methods.

Potassium and sodium were determined directly on the extract, without pretreatment, using the photometer. A comparison of the results obtained by the two methods is shown in Table II. In this case good agreement is obtained by the two methods. Here again the photometric method is much faster than the chemical method because the time consuming evaporating processes are eliminated.

TABLE II—Comparison of the Amounts of Potassium and Sodium Found in 1-1 Water Soil Extracts by Gravimetric Chemical Methods and by the Photometric Method

Sample Number	Ppm Potassium Found		Ppm Sodium Found	
	By the Chemical Method	By the Photometric Method	By the Chemical Method	By the Photometric Method
1	8.3	7.4	64.0	66.0
1	8.1	7.3	70.0	68.0
1	7.6	7.3	73.0	67.0
2	4.5	4.2	38.0	35.0
2	3.9	4.2	33.0	33.0
2	4.5	4.1	33.0	33.0

When ammonium acetate extracts of soil were analysed photometrically the sodium values agreed well with those obtained by chemical methods.

However, the photometric potassium values were lower than the values obtained chemically. This phenomenon also occurred when pure ammonium acetate solution containing known amounts of potassium were analysed photometrically. This, we believe, is caused by interference of the acetate ion, and its removal should overcome this difficulty. Our attempts to eliminate this interference have been limited in scope, and have led to other difficulties.

SUMMARY

A very rapid method of determining potassium and sodium in plant material by the use of a flame photometer is described. The method has the advantages of speed, low cost of chemical reagents, and ease and simplicity of operation without sacrifice of accuracy.

1-1 water extract of soil may be rapidly analysed for potassium and sodium with good accuracy by the method described.

Ammonium acetate extracts of soils may be analysed directly for sodium by the method. The method gives low values for potassium on ammonium acetate extracts of soils.

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Method for Separating Root Tissue from Root-Gravel Mixtures

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IN connection with researches to determine the function of the rubber hydrocarbon (caoutchouc) in the guayule plant, *Parthenium argentatum* A. Gray (4), it was necessary to recover quantitatively the new roots formed during the experimental period. The writer knew of no suitable procedure and one had to be devised. The method is based on the two forces — static electricity and gravity. When guayule tissues were ground in the hammer mill, it was necessary to provide a ground wire to remove the static electric charge from the tissue particles; otherwise it would have later interfered with the sampling procedure (5). This suggested the basis for the present method.

Only simple apparatus is required, and suitable substitutes may replace the articles used in the present case: No. 10 U. S. Bureau of Standards sieve with receiver (pan); pyrex baking dishes, 8½-inch top diameter, 6-inch bottom diameter, and 3 inches deep; "camel's" hair brush, hair length 1¼ to 1¾ inch, handle 3½ inches long; a large sheet of smooth paper; a silk (natural) cloth; and a 20-mesh 5 by 5 inch square of wire screen.

The nature of the electric charges on the dry guayule tissue, and the glass container were first considered. According to Gortner (1), plant tissues in general have a negative charge, and Moore (2, 3) has pointed out that cellulose has a negative charge. By making use of the silk (natural) and fur on glass (annealed watch glass) test, the electric charge on dry ground guayule tissue was determined as negative and that on the glass dish as positive. It was noted that ground guayule tissue was attracted to the inside of the pyrex glass baking dishes at all times under the conditions of the lower Salinas Valley of California. It was realized that should the attraction be insufficient for the purposes of the present method, the electric charge could be increased by briskly rubbing the inside of the dishes with a natural silk cloth.

The plants were taken from the ½-gallon crocks in which they were grown under gravel culture. An analysis of the particle sizes of gravel, grade B, as used in the guayule experiment, is shown in Table I, in comparison with gravel of grade A, not used in the present experiment. It should be noted that the use of the latter or a similar grade would facilitate the separation of the roots from the root-gravel mixture (see Table II). The top portion of the gravel was first carefully poured off while the plant was still in the crock. The whole plant was then removed with a ball of gravel around the roots. While the ball of gravel containing the roots was held by the hand from the bottom, the root portion of the plants was immersed in a large volume of water. The loose gravel was allowed to fall to the bottom until practically all of it was removed from the roots. The new roots with adhering gravel were then removed from the original tap root. Any

TABLE I—ANALYSIS OF PARTICLE SIZES; GRAVEL GRADES A AND B

U. S. Bur. Standards screens				Amount Recovered*		Per Cent Recovered*	
No.	Mesh	Size of Openings		Grade A	Grade B	Grade A	Grade B
		(Inches)	(Microns)	(Grams)	(Grams)		
10	9	.0787	2000	163.0	40.00	81.50	20.00
20	20	.0331	840	35.00	146.0	17.50	73.00
40	35	.0164	420	1.0	12.0	0.50	6.00
60	60	.0098	250	0.1	1.0	0.05	0.50
80	80	.0070	179	0.05	0.4	0.025	0.20
100	100	.0059	149	0.1	0.1	0.05	0.05
200	200	.0029	74	0.0	0.0	0.00	0.00
Pan	—	—	—	0.05	0.0	0.025	0.00
Total recovered				199.3	199.5	99.65	99.75

*200 grams used; difference in total recovery represents experimental error.

branch roots or root hairs left behind in the water were also recovered, although this fraction was very small and within 1 per cent of the total root tissue recovered. All of the gravel surrounding the roots, excepting that attached to the roots already recovered, was poured into the large volume of water, and the water was slightly agitated so that all of the root tissue floated in the water. The root tissue was then seined out with the wire screen. The total root tissue with adhering gravel was then dried at 65 degrees C, in a mechanical convection oven for 48 hours, and stored in air tight containers. The roots were separated from the gravel according to the following procedure:

The dried root-gravel mixture was placed in the No. 10 sieve over the receiver (pan). The mixture was rubbed between the fingers in order to loosen any adhering gravel from the roots, and the sieve was then shaken. The portion of the mixture retained in the sieve was handled separately from that which passed through the sieve into the receiver as indicated in Table II.

TABLE II—METHOD FOR SEPARATING ROOTS FROM ROOT-GRAVEL MIXTURES; SHOWING TYPICAL RESULTS

Nature of Sample	Sieve Separation	Sub-portion Used for Separation Purposes	Tissue (Grams)	Gravel (Grams)	Ratio Gravel/Tissue
New roots, from 16 months old guayule plants after gravel culture for 3 months	Portion retained in No. 10 sieve	Entire Amount	.81	45.66	1.56
	Portion passing through No. 10 sieve	1st	2.01	26.00	1:13
		2nd	2.28	36.41	1:16
		3rd	2.31	33.51	1:15
		Totals	7.41	141.58	

Portion Retained by No. 10 Sieve:—This portion is characterized by the presence of a very small amount of the total tissue, representing the larger sized tissue particles, and the coarser gravel. It can be handled in one operation, if the total amount present is not greater than 50 grams. The larger pieces of root tissue are first removed by means of a tweezer. The remaining mixture is then poured into the pyrex dish. This is held at such an angle from the horizontal that the gravel readily passes to the bottom groove. A portion of the mixture is brushed up over the free surface of the dish bottom, the dish is tapped on the table top in order to bring down any gravel particles that do not readily return to the bottom groove. If the dish is held at the proper angle during this operation, part of the root tissue is not carried down with the gravel but remains in place on the bottom surface of the dish aided by the opposite electric charges on the root particles and the glass surface, and also by the lesser specific gravity, and unrounded shape of the tissue particles. The freed root tissue is then brushed into another dish by means of the "camel's" hair brush. For convenience, the two dishes are set on a large sheet of smooth paper so that any tissue falling outside the receiving dish when brushed may be easily recovered. The whole operation is repeated until the tissue is infinitely diluted in the mixture, leaving gravel practically free from root tissue. As an aid in the final stages, when the amount of tissue has been much reduced, the brush may be drawn through the mixture in one direction as the dish (held at an angle) is rotated in the opposite direction. Tissue particles will be freed from the mixture and adhere to the glass surface in the groove, and can be brushed into the dish containing the root tissue.

Portion Passing through No. 10 Sieve:—The maximum quantity of the mixture that can be conveniently handled is about 40 grams. If the total is greater, sub-portions should be used for purposes of separation as shown in Table II, where three were required in the example cited. Since the particle sizes are smaller, and the ratio of tissue to gravel is greater, the problem is somewhat different in the present case. The glass dish is tilted upwards, away from the holder at an angle of 20 to 30 degrees from the horizontal, and the mixture in it is rapidly agitated by a circular shaking notion through a very small circle. (This operation must be learned by preliminary practice). A portion of the guayule tissue will remain in the elevated upper area of the dish bottom, and the gravel with some tissue will collect at the depression toward the person shaking the dish. The tissue free of the gravel is brushed out into the other dish. This operation is repeated until only a relatively small proportion of the tissue remains in the mixture, and this approach yields only a little return for the effort expended. When this stage is reached, the procedure outlined in the previous paragraph is followed until the proportion of tissue to gravel is so small that any tissue left behind will be within the allowable experimental error, depending on the degree of accuracy required.

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Some Statistical Problems Confronting Horticultural Investigators[1]

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No attempt will be made to cover all the problems that confront horticulturists. In fact the discussion will be confined to three aspects of planning experiments in biological research:

1. The choice of treatments
2. Sampling techniques
3. Experimental designs

The remarks may well be prefaced by an excerpt from a paper which Dr. B. T. Shaw presented at the meetings of the American Society of Agronomy in March, 1946.

"There are many experimental problems that are interesting, but among them are those that are not only interesting but have intrinsic value because of their implications. Before proceeding I should like to point to an example that I feel characterizes some of our present agricultural research. Suppose we brought a high school student into a laboratory and provided him with several batteries, wires of various lengths, diameters, and materials, an ammeter, and a voltmeter. We then instruct him to connect the wires in various combinations to the batteries and meters and record his observations. This would be an interesting exercise and in the course of time he would amass a vast amount of data. But all the data he could accumulate may be expressed in the simple statement of Ohm's law. Some of our agricultural experimentation is in the category of the exercise proposed for the high school student. We start with soils that vary in all sorts of ways, we apply various treatments, and we record crop yields. We amass all kinds of data. It would seem that it should be possible to develop generalizations for correlating most of these results. To do so will require that we make adequate characterizations of the sites of our field experiments . . . If we accumulate vast quantities of experimental data that is not very well motivated, it seems that we could waste a lot of time. What I think we should do, is to consider our experimental objectives in detail and then select sites for our field experiments that will permit the development of generalizations from the results that will have wide applications."

THE CHOICE OF TREATMENTS

A basic assumption involved in establishing any particular experiment is that the quantitative differences between the treatments are not known and that they may be estimated from the contemplated test. There is little reason to include any particular treatment except to achieve this end. In 1926 Fisher (2) proposed a new system of evaluating treatments, which he called the factorial experiment. It provides for testing one class of treatments, such as degrees of pruning over a range of variations in another type of treatment, say varieties. The technique has been rather widely used and has rendered very valuable, fundamental data. It provides for obtaining two kinds of information: (a) the average effects of the different degrees of pruning when tested on several varieties, and (b) the interaction or differential response of degrees of pruning when used on different varieties. These two kinds of information can only be obtained from a factorial scheme. However, the factorial experiment cannot be regarded as fool-proof or as a cure-all.

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In setting up a fertilizer experiment in the low fertility soils of the Southeast, it may be desired to test three levels of N P K. A complete factorial arrangement of these elements would require 27 treatment combinations and if tested in three replications, 81 plots would be used. However, the most advantageous use of the available facilities may not require the complete factorial scheme. A large number of fertilizer experimnts have been performed in the past 50 years using many different crops. Already considerable information has been accumulated on the nature of the interactions of N P K if the starting levels of these elements are known. Therefore, in several instances, an intensive study of the complete factorial may not be the most efficient procedure.

Where some previous information is available on the nature of the interactions and approximately the maximum quantities of each element required by the crop, an alternative system has given good results. A set of seven treatments would provide three levels of each of the three elements tested in the presence of maximum levels of the other two.

Treatment Number	N	P	K
1	1	3	3
2	2	3	3
3	3	3	3
4	3	1	3
5	3	2	3
6	3	3	1
7	3	3	2

This group of treatments obviously makes heavy demands on treatment number 3, since it provides the third point in each of the three curves. It may be desirable to include this treatment twice in each replication to insure its accuracy. Six replications of these seven treatments would require only 42 plots, approximately half the number used in three replications of the complete factorial. Thus the accuracy of each treatment included would be considerably enhanced and the time saved could be devoted to a more adequate characterization of the experimental site.

This discussion is not intended to decry the usefulness of factorial experiments, for there is a definite place for them. Rather it is an attempt to point out the desirability of requiring that every treatment in an experiment be included on the basis of what it can contribute to the desired information rather than as fiiller to complete a particular system.

SAMPLING TECHNIQUES

After the treatments are chosen, the next problem encountered in planning an experiment is the preparation of suitable techniques for obtaining the data. The choice of the most efficient techniques often involve statistical reasoning. For example, in order to ascertain the nutrient status of the soil, a sample must be drawn and analyzed in the laboratory. How shall the sample be drawn? What intensity of sampling should be used? How accurately can the laboratory subsampling and analysis be done? These are questions which have to be answered every time any sample is taken.

There are several suggestions in the literature on the subject, but few of them have been adequately tested. Some proposals recommend that a certain number of borings be taken "at random" from the area to be characterized. A moment's reflection will point to the physical difficulties involved in such a procedure. A more suitable approach would be to prescribe some systematic pattern for placing the borings in the area, composite the necessary number of borings and subsample the composite for analysis. However, statisticians have been slow to provide methods of evaluating such a procedure.

Recently 20 fields in eastern North Carolina were sampled in such a way as to provide a little information in this regard. Each field was about 8 acres in size and the cropping history and soil type was fairly uniform within each area. The fields were long and narrow and were subdivided into 4-acre halves. Duplicate composites of 20 borings each were drawn from every 4-acre block. The borings were distributed over the area in a zig-zag path which approached a grid pattern and each grid was started at random. Differences between duplicate grids provided a basis for evaluating the accuracy of a single systematic set of 20 borings. It was found that from such a pattern in a 4-acre block the base exchange capacity, organic matter and exchangeable calcium could be measured to within 12 to 17 per cent of the true field average. On the other hand, the confidence limits on constituents which had been applied in restricted bands, such as exchangeable potassium and magnesium and soluble phosphorus, ran as high as 30 per cent.

Apparently, there is as yet no satisfactory method of determining what might be expected from changing the number of borings in the pattern. This is a problem which could profitably attract the attention of statisticians in the immediate future.

There is another type of sampling problem confronting horticulturists. Great strides have been made recently in perfecting analytical techniques for determining the mineral and vitamin content of plant tissue. The precision of the tests has been improved and the labor involved has been greatly reduced. However, there has not been a commensurate development of procedures for drawing the samples to represent accurately a specified population. In this case the statistical devices are available but have not been used extensively. Several sampling studies have been reported but there is a need for many more in order to provide a broad background for sound judgment in solving single problems.

Again an example from the laboratories of North Carolina State College will illustrate the techniques available and the types of questions that need answering. It was desired to measure the amount of calcium, magnesium, potassium, and phosphorus in strawberry tissues during the growing season. Some of the questions posed were:

1. What plant parts should be sampled? Mature leaves, young leaves or runner plants?
2. How many leaves or plants should be taken per plot?
3. Since analyses were to be made on fresh tissue, how should the field sample be subsampled in the laboratory?
4. How do sampling and subsampling variations compare with errors of determination in the laboratory?

In an attempt to answer these questions, two replications of three fertilizer treatments were sampled. Three samples of each of the plant parts — mature leaves, young leaves and runner plants — were taken from each plot. The samples were finely chopped with a knife and duplicate 5-gram subsamples were drawn. Duplicate determinations were made on each subsample.

The most suitable plant part proved to be the mature leaves because of their sensitivity to changes in fertilizers, their apparent uniformity, and their availability in 50-foot plots. A single analysis of variance for PO_4 in mature leaves will illustrate the other features (Table I).

TABLE I—ANALYSIS OF VARIANCE OF PO_4 DETERMINATIONS ON MATURE STRAWBERRY LEAVES

Source of Variation	d.f.	Mean Square	Composition of Mean Square	Estimate of True Variance
Field samples	12	10,178	$s^2_d + 2s^2_s + 4s^2_f$	$404 = s^2_f$
Subsamples	18	8,562	$s^2_d + 2s^2_s$	$4{,}074 = s^4_s$
Determinations	36	415	s^2_d	$415 = s^2_d$

The errors of making the various chemical determinations were very small, ranging below 3 or 5 per cent. Differences between subsamples, however, were startling. There was uncovered in this so-called "usual technique" a serious source of error. The plant material was not chopped finely enough to yield accurate 5-gram subsamples as may be seen in the comparison of the true variance due to subsampling with the other variances. In subsequent studies this discrepancy was almost completely eliminated by stacking the leaflets on top of each other and running a cork borer through the entire pile several times. The variation between field samples for the other constituents was of such a size that a 100-leaf sample was recommended for future studies.

There is considerable evidence that inadequate sampling techniques constitute one of the weakest links in agricultural research programs.

EXPERIMENTAL DESIGN

At the very outset it is desirable to emphasize two points. First, a rather intimate contact with several hundred analyses involving almost every conceivable type of design leaves one with an almost reverent attitude toward a simple randomized block design. The second point is that for field experiments considerable thought should be given the problem before using a layout which cannot be alternatively analyzed as a randomized block. The risks involved in the loss of a section of the test area or the failure of certain treatments are seldom justified on the basis of possible gains in precision. This of course refers primarily to confounded or incomplete block designs which are not set up in complete replications.

This apparent conservatism is offset by a high enthusiasm for the group of incomplete block designs known as the lattices.

In such designs, soil or other environmental variations can be controlled in units smaller than a complete replication. In a 5 x 5 lattice, for example, 25 entries are tested in a single experiment, yet the error term is primarily composed of variation within blocks of 5 plots. The precision of these designs is customarily expressed in relation to randomized complete blocks. A relative precision of 150 would indicate that the error for the lattice was 100 per cent, but would have been 150 per cent if the variation between blocks within replications had not been eliminated. Stated another way, in order to get the same degree of accuracy as obtained in the lattice, 50 per cent more replications would be needed.

The laboratory of the Institute of Statistics of North Carolina has analyzed over 200 lattice designs in the last 5 years. It would be difficult to give a complete summary of the results here, but they can be adequately illustrated with the results from corn. Thirty-five tests of various kinds of 4 x 4 lattices averaged 142 in relative precision, 55 experiments with 5 x 5's averaged 164, and 43 7 x 7's gave 151. Larger designs would of course be expected to show increases in precision. These gains may be expressed in terms of reduction of plots used. In order to get the same amount of information from these 133 corn tests in randomized complete block designs, approximately 8,000 additional plots would have been required.

There is no reason to believe that similar results would not be obtained from horticultural crops which use the same size plots as corn, although our experience in this regard has been limited. Three 5 x 5 simple lattices testing strawberry varieties gave precisions of 152, 120, and 101.

With the possible exception of some West Virginia results reported by Wellhausen (3) most published reports indicate that lattices are primarily useful in testing large numbers of varieties only. A test of 25 entries has been commonly regarded as the smallest in which a lattice would be advantageous. Our experiences on the relatively heterogeneous soils of the South and East do not bear this out. As indicated above, variety tests involving only 16 entries have given sizeable gains in precision due to the extra restrictions. Fertility tests usually involve much larger plots than variety comparisons and they too have given satisfactory increases in precision over the randomized block arrangement even when the number of treatments is relatively small. These increases have been evident in studies involving soil borne diseases such as scab of potatoes. For example, one test involving scab readings gave a precision of 117 on a 3 x 3 balanced lattice. Thus it is indicated that a great many of the tests requiring large plots would profit from the use of a lattice design, even though a relatively small number of treatments is involved.

An investigator is seldom satisfied with a single measurement on plants under study. For example, a blueberry test might require data on total yield, number of berries per pound, number of berries per cluster, number of clusters per plant, flavor and other quality ratings, and disease scores. The researcher very quickly discovers that only a few of these are sufficiently sensitive to environmental variations to justify the complete lattice analysis. In such instances, considerable time and effort in computation could be saved by using only a randomized block analysis. As a matter of fact, some experience with lattice designs enables investigators to predict rather accurately from observation of the test during the growing season whether any appreciable gains in precision may be expected from the lattice analysis. After a little experience there is practically no difference in the difficulties involved in setting up and planting a lattice and a randomized block test. Therefore in practice, the use of lattice designs may become a form of insurance against unpredictable field variations. The price paid for the extra precision comes largely in the analysis of the data.

The choice between simple, triple, and balanced lattices is largely one of the number of replications to be used. All of these designs are well liked because of their flexibility in field arrangement. The shape of individual replications can be altered to fit the experimental site. Lattice squares on the other hand are rigid in field design, requiring the replication to be 5 plots wide and 5 plots long in a 5 x 5, for example. The additional restriction in lattice squares has proved quite valuable, however, in certain areas of the South. On terraced land, crop rows run with the terraces. It is almost necessary to place replications end to end and yet fertility or moisture gradients are frequently greatest across the rows. Here the columns of the lattice square should prove beneficial. On some of the poorly drained soils of the Coastal Plains areas open drainage ditches are frequently so located as to cut the fields into long narrow strips. The steepest gradients in plant growth are found across rows. In orchards operations such as cultivation, cover cropping and spraying are performed on complete rows across the field. Here again rather sharp variations may occur in long narrow strips. Under such circumstances as these, lattice squares have literally saved many experiments.

One of the chief criticisms of the lattice designs is the restriction in number of treatments that can be included. Dr. Harshbarger of Virginia Polytechnic Institute has worked out the analysis for rectangular lattices so that this restriction may not be so serious in the future.

There is one other type of confounded design which certainly deserves honorable mention and that is the split-plot arrangement. It frequently happens that in factorial combination of treatments there is little interest in one or more of main effects, but the experiment is planned specifically to evaluate certain interactions. For example, in a date of planting test the objective may be to find varieties which will tolerate extreme dates. The mere mechanics of preparation of the seed bed dictates the use of large units for planting dates. Since varieties can frequently be evaluated on relatively small plots, several varieties can be included in each planting date. The same reasoning could be extended to a great many fertility experiments. If the fertility plots need to be several rows wide, why not plant a different variety in each row that is to be harvested for yield records? By so doing the applicability of the results can be broadened without hazarding the information which might have been obtained by using a single strain.

One caution should be inserted at this point. In such tests two types of comparisons are available — the relation between varieties on any one date of planting and the relation between dates of planting when any one variety is used. These comparisons involve different errors. In the first instance each variety is grown on the same whole plot and therefore variety differences are subject only to variations between sub-plots within whole plots. These comparisons are usually quite accurate. However, testing dates of planting using one variety involves whole plot as well as sub-plot error. Methods of constructing the appropriate errors are given by Cochran and Cox (1). The caution that is needed is in reference to foreseeing the desired comparisons and protecting them in the design. If there is little interest in the average effect of planting dates but keen interest in the interaction, it would be well to determine which aspect of the interaction will be most useful. If the whole plot error is poorly estimated or allowed to become too large, comparisons across whole plots become inefficient.

What has been said may be briefly summarized in the form of recommendations.

1. Be sure that every treatment in an experiment contributes its share of information.
2. Check all sampling procedures for "leaks" in efficiency. They frequently occur at unexpected places in the technique.
3. Use incomplete block designs where control of within rep variation is needed.
4. If large plots are needed in certain types of treatments, additional information can frequently be gained by using several varieties within each large plot.

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Fructose and Other Monosaccharides in Guayule[1]

By HAMILTON P. TRAUB, M. C. SLATTERY, *U. S. Department of Agriculture, Beltsville, Md.,* and E. D. WALTER, *U. S. Department of Agriculture, Albany, Calif.*

IN connection with the guayule physiology research program it was of importance to determine the kind of carbohydrates present in the tissues of the plant (*Parthenium Argentatum* A. Gray). Experiments with this objective were accordingly carried out. The results obtained concerning the chief reserve carbohydrates—levulins and inulin—have been previously reported by Traub and Slattery (8, 9), and those concerning the nature of the free reducing sugars are summarized in this brief note.

FREE FRUCTOSE

The guayule tissues were finely ground as outlined by Traub (7). Total free reducing sugars were first determined on the cold water (20 degrees C) extract of the finely ground tissue by the semi-micro method of Somogyi (6) and total free fructose by Nyns' method (5) as modified by Jackson and Mathews (1). Typical results are reported in Table I, showing that the free reducing sugar content on the dry weight basis in the stems and roots is below 1 per cent, but rises to about 5 per cent in the inflorescence. These results differ from those reported for girasole tubers, *Helianthus tuberosus,* also belonging to the Compositae, by Traub *et al.* (10). According to these workers, girasole tubers "do not contain appreciable amounts of reducing sugars". Table I also shows that fructose comprises a minor fraction, only about 10 per cent of the total free sugars in guayule stems and roots. However, the fructose of the total free sugars in the inflorescence amounts to about 25 per cent. It is of interest to note that the amounts of free non-fructose sugars are always greater than the free fructose fraction in spite of the fact that the chief reserve carbohydrates in guayule are polymers of fructose primarily levulins and inulin as reported by Traub and Slattery (8, 9).

TABLE I—ANALYSES OF GUAYULE

Kind of Tissue	Time of Sampling	Total Free Sugars* (Per Cent)	Total Free Fructose of Dry Weight (Jackson and Mathews)* (Per Cent)	Free Fructose of Total Free Sugars* (Per Cent)
Stems and roots	Winter	0.98 ±.010**	0.09 ±.003**	9.08 ± .27**
Stems and roots	Summer	0.61 ±.010	0.06 ±.009	10.30 ±1.67
Inflorescence	Summer	4.89 ±.020	1.22 ±.050	24.84 ±1.00

*Dry weight basis
**Basis of 4 variates

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[1] Contribution from the Emergency Guayule Research Project, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture. The cooperation of the U. S. Forest Service is gratefully acknowledged.

OTHER FREE MONOSACCHARIDES

Attempts were made to identify the non-fructose free sugars in guayule. Although this portion of the work was not completed when the emergency war assignments terminated, the following preliminary results are reported for what they may be worth to future workers.

Cold water (20 degrees C) extracts of the finely ground guayule tissue were made. Proteins, tannins, etc., were precipitated with neutral lead acetate, and the extracts were deleaded with calcium oxalate or hydrogen sulfide. The clarified extracts were concentrated to lesser volumes under reduced pressure at 55 to 60 degrees C, and the tests were made on aliquots of these solutions.

The mucic acid test for galactose, and the saccharic acid test for glucose were negative. Boiling the free sugar solutions with phenylhydrazine resulted in only one osazone, namely glucosazone, indicating glucose, fructose or mannose, or any combination of these. Since the saccharic acid test for glucose was negative, the osazone apparently could be due to fructose or mannose, or both. A very slight precipitate was formed in the cold, possibly indicating a trace of mannose phenylhydrazone (3), but attempts to recrystalize this, to definitely identify mannose, were not successful.

Attempts to form a potassium aldonate by the procedure of Moore and Link (2) failed. This would indicate that no more than a trace of mannose could be present since glucose is ruled out by the negative saccharic acid test. The qualitative tests here reported apparently rule out glucose and possibly also mannose, and point to the possibility that the major portion of the free sugars in guayule consists of ketoses other than fructose. In the light of these results the possible presence of sorbose should be considered in future work.

In connection with future work, it should be pointed out that difficulty was experienced on account of the salt content of the tissue extracts, and it is suggested that it might be helpful to pass the water solutions through cation and anion exchangers—resins—before carrying out the tests (4).

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An Antibiotic Substance Obtained from Seeds of Brassicas[1]

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IN THE COURSE of a search for antibiotic substances in plant materials it was observed that seed extracts of several species of Brassica exerted an antagonistic effect on the growth of a number of bacteria and fungi. Tests were conducted with several microorganisms; they are given in detail in an article published elsewhere.

Since the antibiotic agent evidently is not formed in the seeds, but only in the process of their maceration with water, it was assumed to be a mustard oil. It has been known for a long time that the volatile oils obtained from crucifers are not present as such in the parts of the plants, from which they can be extracted, but in the form of glucosides. They develop as products of hydrolysis brought about by enzymatic action. The enzyme is present in the same plant organs but in different cells. When the tissues are macerated the enzyme reacts with the glucoside to form the volatile oil. Gildemeister and Hoffmann (1) expressed the opinion that the same enzyme, myrosin, was present in all crucifers although there were different glucosides. However, even now, 30 years later, this has not yet been established beyond doubt. It is known though that myrosin is an enzyme system rather than an enzyme (2), the active principles of which are myrosulfatase and thioglucosidase (3).

Although the manner of occurrence of the antibiotic principle mentioned seems to point to a mustard oil, there are other factors involved which cause certain doubts. Walker, Morell and Foster (4) investigated the toxicity of mustard oils and found allyl isothiocyanate and beta-phenethyl isothiocyanate to be the most toxic ones toward certain microorganisms. Kossowicz (5) and Morel and coworkers (6) established the toxicity of allyl mustard oil against bacteria. Hence, these two mustard oils were synthesized and tested in the same manner as the seed extracts. Neither of the synthetic oils, applied in concentrations far greater than could possibly be obtained from seed extracts, impaired the growth of *Staphylococcus aureus, Escherichia coli*, and *Phytomonas phaseoli*.

Furthermore, seed of a commercially available mustard was extracted and tested, but failed to inhibit the growth of the same organisms. This seed sample[2] was labeled Oriental Mustard, grown in Montana. The extract emitted an extraordinarily pungent odor immediately after its preparation. If the pungency can be taken as an indication of the concentration of mustard oil present, this sample must have contained far more of it than any of the species of Brassica in which the antibiotic principle was found. Some of these, especially the cabbages, did develop some pungency after maceration, but it was not comparable with that of the mustard seed. Others, like broccoli, turnip, rutabaga, and Chinese cabbage had very little pungency or were completely devoid of it. Yet, some of them exhibited a considerable antibiotic effect immediately following their preparation. Turnip and rutabaga seed extracts showed activity only after a storage period. It is not yet known whether this is due to the slow rate at which the fermentation process takes place in these particular cases, or if a substance is formed not connected with the hydrolysis of the glucosides.

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[1] Journal Article No. 804 (n.s.) from the Michigan Agricultural Experiment Station.

[2] Obtained through the courtesy of Leslie Edgerton Seed Company, Minneapolis, Minnesota.

The tests for the presence of antibiotic substances in plant materials were made according to a modification of the procedure developed by Vincent and Vincent (7). The substance to be tested was incorporated in small filter paper discs which were in Petri dishes on an agar medium inoculated with a culture of the microorganism chosen for the test. The circles of inhibition that developed around the discs were measured after a given time and the measurement was used for the evaluation of the effect.

A comparison of the results obtained with the extracts of several species of Brassica and numerous varieties of *Brassica oleracea* indicates that the reactions are rather specific. Further examinations will show whether the specificity is a varietal characteristic or influenced by environmental conditions.

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The Effect of Bottom Heat on the Yield of Forced Rhubarb[1]

By E. H. BJORNSETH,[2] *Michigan State College, East Lansing, Mich.*

LATE RHUBARB is usually forced at temperatures ranging from 10 to 15 degrees C. At temperatures in the range of 15 to 21 degrees C the growth of the petiole is faster but the formation of anthocyanin is reduced resulting in a lighter red petiole that is inferior in sales appeal to the dark red petiole that develop at a lower temperature.

Sayre (2) forced rhubarb at temperatures of 10, 15, 20, 25 and 30 degrees C. The temperatures of 25 and 30 degrees C produced weak spindly petioles that quickly succumbed to soft rot. Collins (1) in some unpublished work had similar experience using bottom heating with an electric soil-heating cable. He did not control the air temperature thermostatically, but he attempted to control the soil temperature by regulation of the electricity with a rheostat.

The present paper deals with an attempt to maintain a low, controlled temperature in the forcing house (10 degrees C) while providing supplementary bottom heat, so as to promote rapid forcing without loss of anthocyanin.

MATERIALS AND METHODS

Soil heating equipment consisting of soil-heating cable, thermostatic controls and electric meters were installed in the forcing house to provide bottom heat for three beds A, B, and C, of rhubarb roots; (Approximately 64 square feet per bed). One bed, D, was set without soil-heating equipment. The heating cable was looped back and forth at 6-inch intervals across the bed to provide uniform heating of the clumps of roots and soil that were set on the cables.

Two year old Victoria rhubarb roots that were in a quiescent state and ready for forcing were set at the rate of one clump of roots per square foot of bed. The spaces between the clumps were filled with dirt. The thermostats were adjusted to maintain soil temperatures of 13, 18, and 24 degrees C in the beds. Forcing was begun on January 4, 1946.

The temperature in the forcing house as recorded on the hygrothermograph was fairly constant between 10 and 13 degrees C, although during the last week of the forcing period, the temperature fluctuated between 4.4 and 15.5 degrees C. The relative humidity in the forcing house was also constant at approximately 100.

The soil temperatures were recorded at several intervals, and the kilowatt hours of electricity used were recorded for each plot (Table I and *Electrical Energy Required.)* The heating of the beds was terminated at the time of the first harvest, February 4.

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[1] Journal Article No. 828 (n.s.) from the Michigan Agricultural Experiment Station.

[2] The writer wishes to express his thanks to Dr. Hugh Gauch, Dr. H. B. Tukey and S. B. Apple for assistance with the manuscript; to The Detroit Edison Company for electrical equipment; and to Raymond Durussel of Utica for his cooperation in providing assistance, facilities and rhubarb for forcing.

TABLE I—Soil Temperatures

Dates	Degrees C			
	Plot A	Plot B	Plot C	Plot D
January 12	14.4	18.8	26.6	7.2
January 15	13.0	19.0	25.0	8.0
January 29	13.0	17.3	26.5	10.0

These recorded temperatures appear to be fairly constant for each plot, however, there was a difference in the rate of application of heat. Observations of the meters showed that the beds that were maintained at the higher temperatures also had the most continuous application of heat. For example, the meter on plot A, intermittently was recording kilowatts of electricity consumed, while the meter on plot C, was recording more continuously.

Electrical Energy Required:—Beds A, B, and C, required 106, 352, and 637, kilowatt hours of electric current to maintain the respective temperatures in these beds for the period of January 4 to February 4, 1946.

Observations on growth, data on yields, and grades per pulling were recorded and averaged to provide information on the early yield of petioles and total yields per square foot for each of the treatments.

YIELDS

Yields of Various Grades:—The yield of fancy grades were 5.91, 4.55, 3.28 and 4.01 pounds per square foot for plots A, B, C, and D, respectively, while the yield of the choice grades was 1.46, 1.39, .96, and .83 pounds per square foot.

The rhubarb was graded according to the accepted arbitrary standards of the trade in "Fancy" and "Choice" grades. The "fancy" grade consists of large petioles that were highly colored with anthocyanin, while the "choice" grade contains the smaller petioles and those that are not as highly colored.

Total Yield:—The total yield of petioles per square foot for the entire cultured period of 67 days for these plots was highest (7.37 pounds) for Plot A, receiving bottom heat of 13 degrees C followed by Plot B (5.94 pounds), receiving bottom heat of 18 degrees C and Plot D (4.83 pounds), receiving no bottom heat, and Plot C (4.24 pounds), receiving 24 pounds C of bottom heat.

Early Yield:—However, the early yield of petioles on beds A, B, and C, that received bottom heat was substantially greater than the early yields of petioles on bed D, that was grown without bottom heat. For example, between February 4, and 15, the percentages of the total yield harvested for each plot by February 15, were 59, 66, 67 and 39.6 per cent for plots A, B, C and D, respectively.

DISCUSSION

The use of bottom heat in the forcing of rhubarb increased the amount of early rhubarb. If the yield per pulling for each of the treatments are plotted it will be observed that the early growth rate is accelerated by the use of bottom heat at 13 degrees and 18 degrees C as compared to the usual method of heating. At a soil temperature of 24 degrees C the growth rate was the slowest, however the early yield was greater than the early yield from the plot D, that did not receive bottom heat (Figs. 1, 2, and 3).

The larger total yields per square foot of bed from the plots in which the soils were kept at 13 and 18 degrees C was due to the greater early yield on these plots. The smallest total yield and the slowest growth was from the plot with soil at 24 degrees C. It is apparent that soil temperatures between 13 and 18 degrees C increased the total yield of rhubarb while temperatures above this range decreased the yield as compared with yields of rhubarb from the plot without bottom heat.

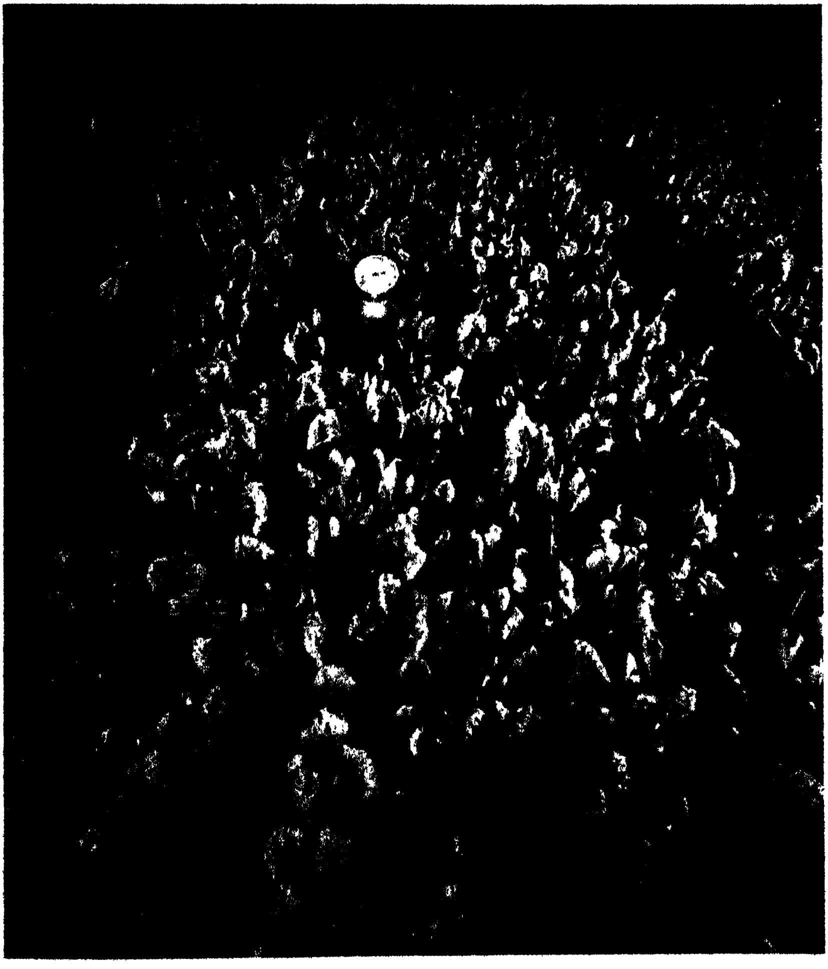

FIG. 1. Rhubarb forced at 10 degrees C without bottom heat (25 days after forcing.)

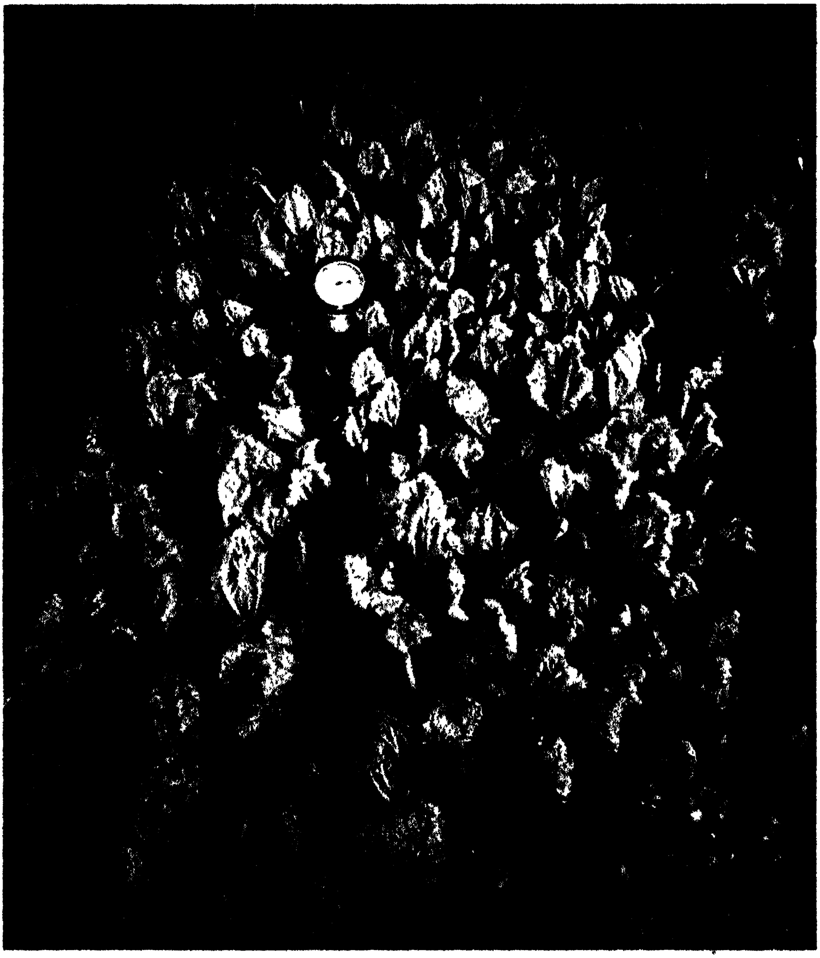

FIG. 2. Rhubarb forced at 10 degrees C supplemented with 13 degrees C of bottom heat (25 days after forcing.)

The difference in early yields and total yields may be due to direct effect of variations in the soil temperature for the plots or to the different rates of heating the soil. In the plots where the application of bottom heat was regulated to keep the soil temperature at either 13 or 18 degrees C the roots and soil were exposed to intermittent periods of heating as the thermostatic control switched the current on and off within its temperature limits of 1 to 2 degrees C. This intermittent heating probably affected the rate of hydrolysis of foods and their assimilation by the plant. The rate of soil aeration may have been increased by the changes in the rate of heating and resulted in an increase in the respiration rate of the roots permitting more favorable physiological activity for growth than at a constant temperature that

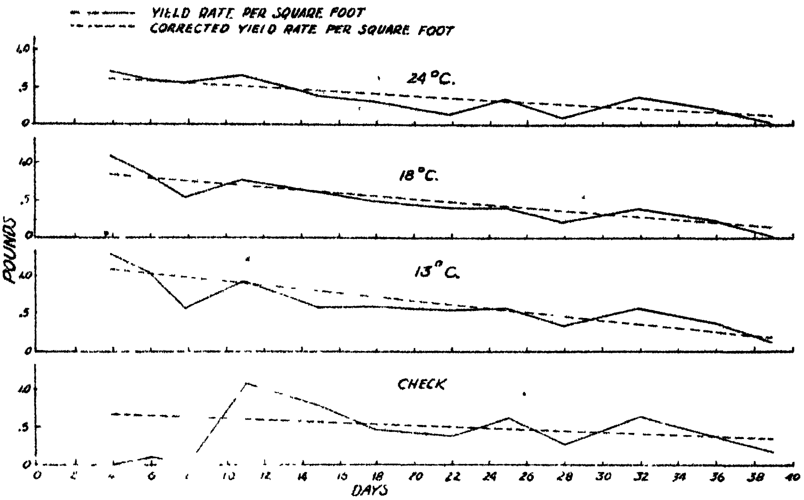

FIG. 3. Yield rates of rhubarb grown with and without bottom heat during a 36-day harvest period.

was either lower or higher than the range of 13 to 18 degrees C. The rate of cation and anion exchange between the root and soil colloids may also have been affected by variations in temperature. Jenny (3) refers to thermal oscillations of cations and anions and implies that the rate of contact and base exchange is modified by changes in temperature.

The application of bottom heat increased the yield of rhubarb designated as fancy on the plots kept at a soil temperature of 13 and 18 degrees C and decreased the yield of fancy rhubarb on the plot kept at a soil temperature of 24 degrees C as compared to the check plot kept at 10 degrees C. The per cent of the total amount of rhubarb harvested as fancy grade per plot decreased with the higher soil temperatures in the forcing bed. However, these decreases were offset by the greater early yields of the fancy grade and total yields per square foot from the plots with soil temperatures at 13 and 18 degrees C. Plot D, with a soil temperature of 24 degrees C produced the least amount of fancy grade and the smallest total yield. (Table II).

CONCLUSION

Rhubarb that is in a quiescent state when forced with room heat of 10 degrees C supplemented with bottom heat of 13 to 26 degrees C will produce a greater percentage of the total yield early. The greatest increase in early yield was obtained with bottom heat maintained at 13 degrees C. The increase in early yield from the use of bottom heat was 130 per cent for 13 degrees C, 105 per cent for 18 degrees C, 49 per cent for 24 degrees C as compared to no bottom heat.

The total yield was increased on the plots receiving bottom heat at 13 and 18 degrees C and was reduced for the plot receiving 24 degrees C of bottom heat. The increases in total yield were 53 per cent for 13

TABLE II—Yields per Square Foot of Forced Rhubarb with and without Bottom Heat.

Dates of Harvest	No Bottom Heat Plot D			Bottom Heat 13 Degrees C Plot A			Bottom Heat 18 Degrees C Plot B			Bottom Heat 24 Degrees C Plot C		
	Yields Per Grade in Pounds			Yields Per Grade in Pounds			Yields Per Grade in Pounds			Yields Per Grade in Pounds		
	Fancy	Choice	Total	Fancy	Choice	Total	Fancy	Choice	Total	Fancy	Choice	Total
Feb 4	—	—	—	1.14	0.13	1.27	1.02	0.16	1.18	0.61	0.09	0.70
Feb 6	0.07	0.02	0.09	0.89	0.15	1.04	0.73	0.10	0.83	0.52	0.07	0.59
Feb 8	—	—	—	0.49	0.08	0.57	0.44	0.09	0.53	0.46	0.09	0.55
Feb 11	0.96	0.10	1.06	0.76	0.17	0.93	0.61	0.15	0.76	0.53	0.11	0.64
Feb 15	0.61	0.15	0.76	0.47	0.10	0.57	0.46	0.15	0.61	0.30	0.08	0.38
Feb 18	0.38	0.08	0.46	0.47	0.10	0.57	0.33	0.15	0.48	0.20	0.10	0.30
Feb 22	0.31	0.07	0.38	0.43	0.09	0.52	0.29	0.10	0.39	0.10	0.02	0.12
Feb 25	0.52	0.10	0.62	0.42	0.13	0.55	0.25	0.14	0.39	0.23	0.10	0.33
Feb 28	0.24	0.03	0.27	0.25	0.07	0.32	0.14	0.06	0.20	0.05	0.04	0.09
Mar 4	0.51	0.12	0.63	0.36	0.19	0.55	0.20	0.17	0.37	0.20	0.15	0.35
Mar 8	0.28	0.10	0.38	0.17	0.19	0.36	0.08	0.12	0.20	0.08	0.11	0.19
Mar 11	0.13	0.05	0.18	0.06	0.06	0.12	—	—	—	—	—	—
Total	4.01	0.82	4.85	5.91	1.46	7.37	4.55	1.39	5.94	3.28	0.96	4.24
Per cent	83	17	100	80.3	19.7	100	76.5	23.5	100	76.3	22.7	100

degrees C and 23 per cent for 18 degrees C with a reduction in total yield of 12 per cent for 24 degrees C. It was evident that 24 degrees C was above the optimum root and soil temperature for the forcing of rhubarb.

The use of bottom heat in the forcing of rhubarb reduced the percentage of fancy grade and increased the percentages of the lower grade designated as "choice". The percentages of the total amount of rhubarb harvested for each plot as "fancy" grade were 80.3 per cent for 13 degrees C, 76.5 per cent for 18 degrees C and 76. 3 per cent for 24 degrees C as compared to 83 per cent for the plot that was not supplied with bottom heat. However, these slight decreases in the per cent of the total amount harvested as fancy grade were offset by the greater yield of fancy grade per square foot on the plots that were maintained with a bottom heat of 13 and 18 degrees C. The plot in which the bottom heat was maintained at 24 degrees C provided less fancy grade rhubarb per square foot of bed than the check plot.

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The Effect on Yield of Freezing and Various Ethylene Treatments in Breaking the Dormancy of Rhubarb[1]

By E. H. Bjornseth,[2] *Michigan State College, East Lansing, Mich.*

Freezing with temperature at (20 degrees F for 2 weeks) according to Sayre (4) is sufficient to break the rest period of rhubarb *(Rheum Rhaponticum)*. Frequently weather cold enough to break dormancy does not occur until after the opportune time for forcing rhubarb for the early market. It is evident that any artificial means of control over the rest period during some years would be advantageous.

Different agencies such as heat, cold, increased and decreased water content, anesthetics, gas, bases, acids and salts have been used on various perennial herbaceous plants as means to start the phenomena of growth. A resume by W. L. Howard (2) regarding the mechanism involved in these various methods for breaking the rest period records the following observations and theories:

Ether and chloroform induces buds to open 3 to 6 weeks earlier than normal. These agents are effective only at the beginning and near the end of the rest period.

Hot water imparts a distinct shock to the cell protoplasm and tissue and acts as a solvent in softening up the winter protecting scales inclosing the leaf and flower buds.

Etherization causes a coagulation and dehydration of the protoplasm. It has been pointed out that dehydration occurs only after the ether has severely injured the tissue. One investigator states in regard to anesthetics, "Their effect upon the plant is to arrest growth and remove moisture from the cell protoplasm, and through these physiological derangements, impart a severe shock to the whole plant which when removed causes a decided growth reaction". He also believes that toxic substances such as acetone and alcohol and non-toxic agents such as freezing, vacuum treatments and desiccation arrest growth and remove moisture from plant tissues in much the same manner as anesthetics.

It has been shown that dehydration occurs only after the ether has severely injured the tissue, and that desiccation cannot be caused by mild doses of ether which are effective in breaking the rest period. It has also been shown that ether and chloroform affect plants by checking some of the changes within the plant cell, while at the same time increasing respiration. F. E. Denny (1) found that dormant potato tubers sprouted freely when exposed to ethylene chlorhydrin vapor. He also showed that the results from ethylene were not encouraging when used in concentrations varying from 75 per cent to 1 part in 5 million for periods varying from 1 hour to 7 days; and in no case did the stimulation produced compare favorably with ethylene chlorhydrin treatment. It has also been reported that when ethylene treatment was continued for a longer period (1 month) the dormant period of the potato tuber was shortened.

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The length of the rest period also influences the yield and rapidity of growth of rhubarb. Rest periods of 6 to 10 weeks are essential to maximum yields. Strawberry and Victoria are the varieties usually grown in Michigan for forcing. Victoria becomes dormant about 2 weeks earlier and requires a longer rest period than Strawberry. Consequently, the Victoria is grown for late forcing. There have been a few years when the weather has been cold enough to break the dormancy of rhubarb during mid-November, permitting earlier forcing with harvest 4 to 5 weeks later.

MATERIALS AND METHODS

Artificial freezing in storage and treating with various chemicals were considered as means to break the rest period of rhubarb. Arrangements were made to freeze rhubarb roots in a cold storage and to treat some of the roots with ethylene gas.

Strawberry rhubarb roots that appeared dormant on October 31, were plowed out on November 1. They were allowed to cure or dry in the field for 5 days. Excess dirt was removed from the clumps by shaking. Fifty-six roots were frozen at 8 degrees F on November 7, and were kept at this temperature for 48 hours. The roots were placed in the root house to thaw and forcing was started on November 14. A temperature of 70 degrees F was maintained in the growing shed.

Forty-eight of the frozen roots were forced along with forty-four roots that had been treated with ethylene gas. The roots were exposed to ethylene for durations of 6 to 72 hours and to various concentrations of ethylene. Twelve roots were forced without treatment. For details on treatments see Tables I and II.

TABLE I—YIELDS IN POUNDS OF RHUBARB PETIOLES PER ROOT AFTER TREATMENTS WITH ETHYLENE 2 PARTS PER 1000 PARTS OF AIR FOR DURATIONS OF 0 TO 72 HOURS

Dates Harvested	Treatment Number and Hours of Treatment							
	Check	No. 1	No 2	No. 3	No. 4	No. 5	No. 6	No. 7
	0	6	12	24	36	48	60	72
Jan 2	—	—	0.44	0.44	0.19	—	—	—
Jan 7	—	0.62	1 06	0.88	0.31	0.62	0.44	0.25
Jan 12	0.98	1.12	1.12	0.69	0.75	1.50	0.75	0.81
Jan 18	0.77	0.56	0.44	0.75	0.75	0.75	0.56	0.75
Jan 24	0.48	0.31	0.62	0.88	0.37	0.56	0.37	0.37
Jan 31	0.50	0.50	0.50	0.75	0.50	0.94	0.25	0.19
Feb 12	0.25	0.19	0.19	0.37	0.31	0.25	0.06	0.06
Totals	2.98	3.30	4.37	4.76	3.18	4.62	2.43	2.43

Two galvanized watering tanks with volumes of 24 and 96 cubic feet were used for the gas chambers. The roots were loosely arranged on an air tight canvas and then covered with the tanks. The ethylene gas was applied from pressure tanks, through an opening in the gasing chamber and then sealed. The amount of gas for each treatment was secured by the use of an ethylene gas regulator. The regulator was

TABLE II—YIELDS IN POUNDS OF RHUBARB PETIOLES PER ROOT

Dates	Check	Treatment Numbers and Exposure to Various Concentrations of Ethylene*							
		No 3	No. 8	No. 9	No.10	No. 11	No. 12	No. 13	No. 14
Jan 2	—	0.44	—	—	—	—	—	0.14	First harvest
Jan 7	—	0.88	0.56	0.62	0.75	1.00	—	0.23	—
Jan 12	0.98	0.69	0.88	1.25	1.43	0.88	0.29	0.34	—
Jan 18	0.77	0.75	0.75	0.56	0.88	0.56	0.31	0.20	—
Jan 24	0.48	0.88	0.56	0.37	0.56	0.62	0.09	0.18	—
Jan 31	0.50	0.75	0.81	0.75	0.69	0.06	0.22	0.13	Last harvest
Feb 12	0.25	0.37	0.50	0.50	0.50	0.37	—	—	—
Total	2.98	4.70	4.06	4.05	4.81	3.49	0.91	1.22	4.09

*Treatments:
Check—No treatment.
3—Roots exposed to ethylene gas 2 parts per 1000 parts of air for 24 hours.
8—Roots watered then exposed to ethylene 2 parts per 1000 parts of air for 24 hours.
9—Roots watered then exposed to ethylene 2 parts per 1000 parts of air for 48 hours.
10—Roots exposed to ethylene gas 4 parts per 1000 parts of air for 24 hours.
11—Roots exposed to ethylene gas 8 parts per 1000 parts of air for 24 hours.
12—Roots frozen at 8 degrees F for 48 hours then exposed to ethylene gas 2 parts per 1000 parts of air for 24 hours.
13—Roots frozen at 8 degrees F for 48 hours.
14—Roots frozen in the field and forced December 7, 1945.

set so that the flow of gas from the cylinder could be controlled at the rate of .2 cubic foot of gas per minute. The temperature in the gasing tank during the treatment was maintained at about 60 degrees F. Each lot of roots was removed from the gas chamber at the end of the time period. This provided for a change of air in the tank at intervals and also made it necessary to replenish the ethylene content of the gasing chamber after the removal of each lot of roots. The rhubarb roots that had been treated with ethylene gas and the roots in the check plot were forced on November 17.

OBSERVATIONS AND RESULTS

The roots that were frozen at 8 degrees F started bud and petiole development early, however, this growth was weak and it appeared the yield would be low. The average yield per root for this treatment was 1.22 pounds of rhubarb. (See Table II.)

The roots that received treatment No. 12, also started rapidly but the growth was weak; the average yield per root being .91 pounds of rhubarb. (See Table II.)

The roots that received the ethylene treatments appeared to be dormant for the remainder of the normal rest period and then started petiole growth at a satisfactory rate. The growth on this rhubarb was as good as the growth of the stalks on those roots that were frozen in the field and then forced at a later date, December 7. There was also a difference in the earliness of growth for the various treatments. The rhubarb roots that had received treatments 2, 3 and 4 produced the earliest rhubarb. The yield per root on these treatments during January 2, to January 7, were 1.5, 1.32, .50 pounds of rhubarb respectively. The plots in which the roots had received treatments 1, 5, 6, and 7, yielded, .62, .62, .44, and .25 pounds per root respectively during the same period. The check plot and the plot that received the freezing and ethylene treatment were later and no rhubarb was harvsted by January 7.

The plots in which the roots received treatments 8 and 9, yielded .56 and .62 pounds of rhubarb per root for the period of January 2 to January 7. The plots in which the roots received treatments 10 and 11, produced .75 and 1.00 pounds of rhubarb per foot during the same period. (See Tables I and II.)

There was considerable variation in total yield for the various treatments. (See Tables I and II.) The roots that were given treatments 1, 2, 3, 5, 8, 9, 10, and 11, produced more rhubarb than the check plot and the rhubarb forced December 7. The roots receiving treatment 4 produced slightly more than the check plot.

Details on the dates of harvest from the rhubarb roots that were frozen in the field and forced December 7, were not completed; however, the first petioles were harvested January 2, and the last harvested on January 31. During this period the rhubarb was pulled six times and produced a total yield of 4. 09 pounds per root.

No data on quality was recorded but it was observed that the plots receiving the ethylene treatments had better quality than those that received the freezing treatment and freezing plus ethylene. (Quality is usually determined by size and color of the stalk.)

Discussion

A satisfactory yield and the earliest rhubarb was obtained from the roots that had received treatments 2 and 3. The total yield from the roots receiving treatment 5 was satisfactory although the early yield was less than the yield from the roots receiving treatments 2 and 3.

The yield from the roots receiving treatments 6 and 7, were 46 per cent lower than the yield from the roots receiving treatments 2, 3 and 5. Apparently, the roots or buds are injured or are inhibited in some way by exposure to ethylene gas for periods greater than 48 hours. Root and bud tissues evidently have a limited capacity for the utilization of the ethylene, during a period of time. The nature of this time factor or plant mechanism involved was not determined. However, it is known that ethylene in small amounts stimulated respiration. Suggested explanations for the inhibiting effect are that concurrently with respiration there is an accumulation of carbon dioxide from oxidation of oxalic acid and sucrose to the extent that the respiration rate would decrease in time.

Ruhland and Wetzel (3) have shown that the malic and oxalic acids in rhubarb are formed by the deamination of amino-acids which in turn are formed by the hydrolysis of proteins. If a normal supply of carbohydrates is available together with the ammonia produced by deamination, an amide will be formed permitting the synthesis of porteins needed for growth. However, if a narcotic is used to stimulate respiration, the synthetic processes will cease and ammonia will accumulate in the tissues in an amount toxic to the plant.

It appears as though ethylene treatments of dormant rhubarb roots to be successful should be made at a concentration and rate to permit absorption up to a capacity for the tissue that will stimulate respiration and oxidation without materially reducing the synthesis of organic compounds used in the growth process.

These ideas are supported somewhat by the results obtained in treatments 10 and 11. Exposure of roots to greater concentrations of ethylene for shorter periods of time did not reduce the yield of rhubarb as much as would be expected at this higher concentration. It is also possible that the diffusion pressure gradient is involved, so that with increases in time of exposure to ethylene the gradient becomes less steep and the rate of absorption of ethylene is reduced.

Summary

The Rhubarb that is dormant will respond and produce satisfactory yields by treating the roots with ethylene, 2 parts to 1000 parts of air for 12 to 24 hours. The plots receiving these treatments were 10 days earlier than those receiving no treatment, but no earlier than plots that were frozen in the field and forced December 7.

Root and bud tissues apparently have a limited capacity for the utilization of the ethylene or are injured by exposure to ethylene for longer periods, as is shown by the reduced yields secured from the roots that were treated with ethylene for 60 to 72 hours.

Ethylene treatments of dormant rhubarb roots to be most effective should be made at a concentration and rate to permit absorption of ethylene up to a capacity for the tissue that will stimulate respiration and oxidation without materially reducing the synthesis of organic compounds used in the growth process.

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Effects of Temporary Shading on Vegetables

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SHADING for some hours daily has been used extensively in photoperiodic experiments to influence flowering. Such shading under non-controlled temperatures, however, not only affects photoperiod but also thermoperiod. Shading in the afternoon will subject the covered plants to dark temperatures (nyctotemperatures) much higher than prevailing during the natural night. Under conditions that the dark processes are limiting growth of plants, due to too low nyctotemperatures, afternoon shading might be expected to cause increased growth and production. On the contrary, when the photosynthetic process is limiting, or when the optimal nyctotemperatures are rather low, shading will not increase production.

A number of experiments were carried out under field conditions, to test the effects of afternoon shading on a number of vegetables. The two largest of these experiments will be described. A preliminary report was published earlier (3).

In the spring of 1944 a set of eight plots was prepared, in each of which nine varieties of vegetables were sown or planted on March 17. A week later black covers (wooden frames covered with black roofing paper) were placed part of each day around and over plots 1, 2, 3, 4 and 6. Plots 5 and 8 were left uncovered all time, and plot 7 was covered with similar frames covered with white cloth, transmitting about 5 per cent of the daylight.

The plots were covered as follows (standard local time):

Plot 1	12:00 to 7:00	Photoperiod 5 hours
Plot 2	13:00 to 7:00	Photoperiod 6 hours
Plots 3 & 7	14:00 to 7:00	Photoperiod 7 hours
Plot 4	15:00 to 7:00	Photoperiod 8 hours
Plot 6	14:00 to 20:00	Photoperiod ± 10 hours

Plants were thinned or harvested when they shaded each other too much.

Table I shows the results, and in Figs. 1 and 2 some of the data have been plotted. It is evident that in some plants any covering reduces production (lettuce, cauliflower). In others there is no significant reduction in production between the controls and the plants receiving an 8 hour photoperiod (beets), and in tomatoes, eggplants and beans a marked increase in production was obtained by covering. Celery showed a typical photoperiodic response. Covering with cloth was either ineffective or less effective than covering with black paper; only in the tomatoes the effect was very good. By removing the covers each night after dark the effect was greatly reduced. The eggplants did not reach the fruiting stage when the experiment was discontinued. When the plants which had developed most in plots 3 and 4 were transplanted next to plants of the same age which never had been covered, they produced ripe fruit some weeks before the control plants.

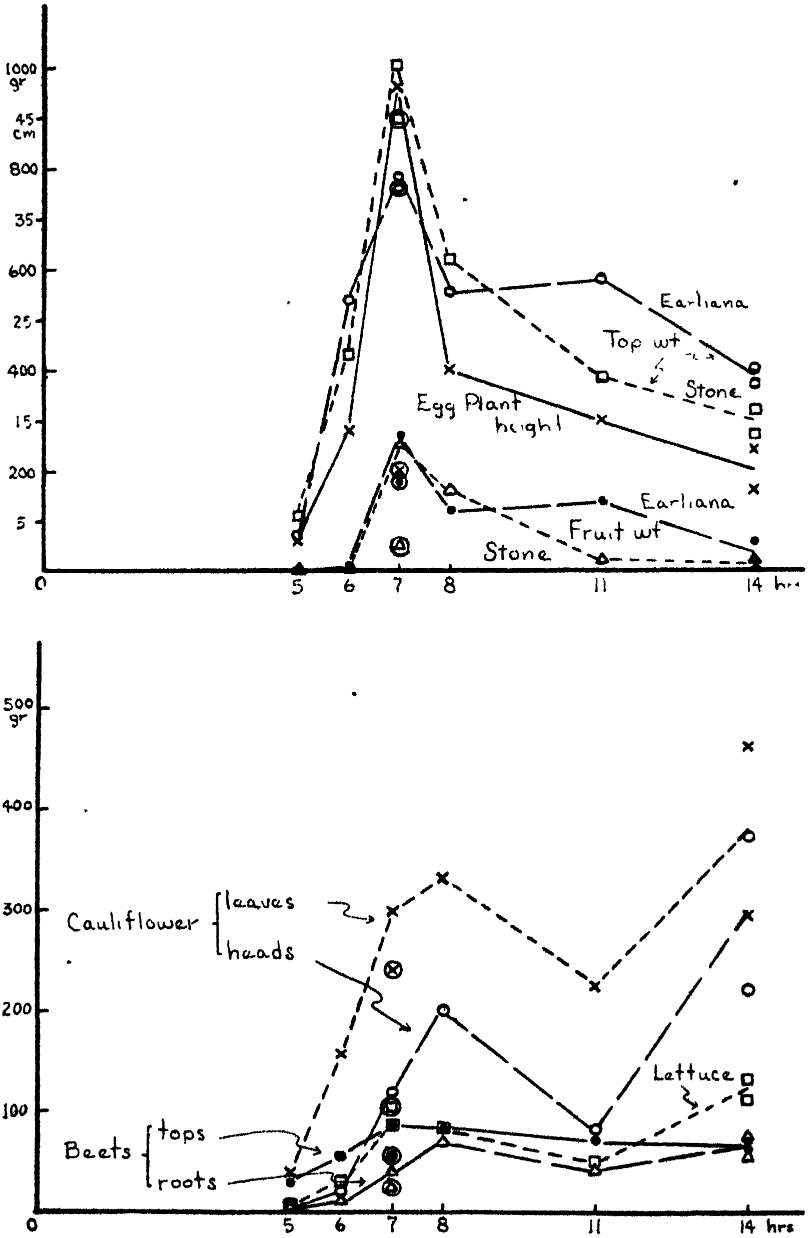
The curve of the tomatoes and eggplants (Fig. 1) has a typical

TABLE I—FRESH WEIGHT (GR PER PLANT) OF VEGETABLES, PLANTED MARCH 17, AND HARVESTED MAY 25 (BEETS), JUNE 1 (CAULIFLOWER), JUNE 3 (TOMATOES, PLANTS A) JUNE 8 (LETTUCE), JUNE 17 (BEANS), AND JULY 5 (TOMATOES, PLANTS B, CELERY AND EGG PLANT)

Photoperiod (Hours)	Controls Not Covered		Covered With Black Paper Frames					Covered With White Cloth Frames
	14	14	5	6	7	8	11	7 +.7 Low Intensity
Plot No.	5	8	1	2	3	4	6	7
Earliana Tomato (4)								
Weight plant A	342	307	37	178	394	416	250	592
Weight plant B	398	369	68	538	781	556	577	759
Weight Fruit	54	20	0	7	272	121	142	178
Stone Tomato (4)								
Weight plant A	275	299	51	174	535	427	350	453
Weight plant B	269	319	109	433	1007	617	385	901
Weight fruit	19	1	0	0	256	161	22	49
Eggplant (4)								
Height plant	12	8	3	14	48	20	15	10
Beans (10)								
Fruit weight	22	120	0	0	58	196	114	259
Cauliflower (8)								
Weight leaves	293	460	38	155	297	330	221	239
Weight head	217	372	3	17	116	197	80	54
Longest leaf, cm	37	39	16	28	31	34	31	38
Number of leaves	19	20	17	19	23	21	21	21
Celery (10)								
Weight plant	187	277	13	110	130	269	96	314
Height plant	54	74	18	29	32	36	32	70
Flowering	+	+	—	—	—	—	—	+
Beets (10)								
Weight top	67	64	26	53	85	83	70	52
Weight root	51	71	4	9	37	67	37	23
Longest leaf, cm	32	31	27	30	32	31	32	36
Number of leaves	11	10	10	10	12	12	11	10
Hanson Lettuce (10)								
Weight plant	131	110	8	30	83	81	49	101
Widest leaf	11	11	5	9	12	12	11	13
Number of leaves	35	36	12	23	29	37	25	33
Great Lakes Lettuce (10)								
Weight of plant	199	198	27	102	85	185	93	98

optimum at 7 hours photoperiod. Presumably at other light intensities and different nyctotemperatures the optimum would be shifted towards longer or shorter photoperiods (2), but it is reasonable to expect that daily exposure to full daylight has to last at least 6 hours, to increase yield, whereas photoperiods over 7 hours would reduce the effective lengthening of the night too much. At lower night temperatures the photoperiod would be shorter than 7 hours, at higher nyctotemperatures the optimum would lie over 7 hours.

In the fall of 1944 (October 1 to December 30) another covering experiment was performed in the field. This time the covering was accomplished with muslin, which was rolled across supports. Two series of plots were used; in one the light intensity was decreased to



FIGS. 1 and 2. Wet weight of tops, fruits, leaves or roots, in grams per plant, of various plants grown in the field in spring. On abscissa are plotted the number of hours that the plants were exposed to full daylight. The symbols surrounded by circle at the 7 hour exposure refer to plants covered with cheesecloth instead of roofing paper.

30 per cent, in the other to 10 per cent of normal daylight. One plot of each series was never covered, another plot remained covered 24 hours per day, and the others received full daylight for 4, 6 and 8 hours daily, being covered the rest of the time. Six varieties of tomatoes were grown in each plot; their general behavior was the same, and therefore the mean of all is presented in Fig. 3.

The light cover did not seem to have an effect on growth and fruiting, the values for partial covering are intermediate between the con-

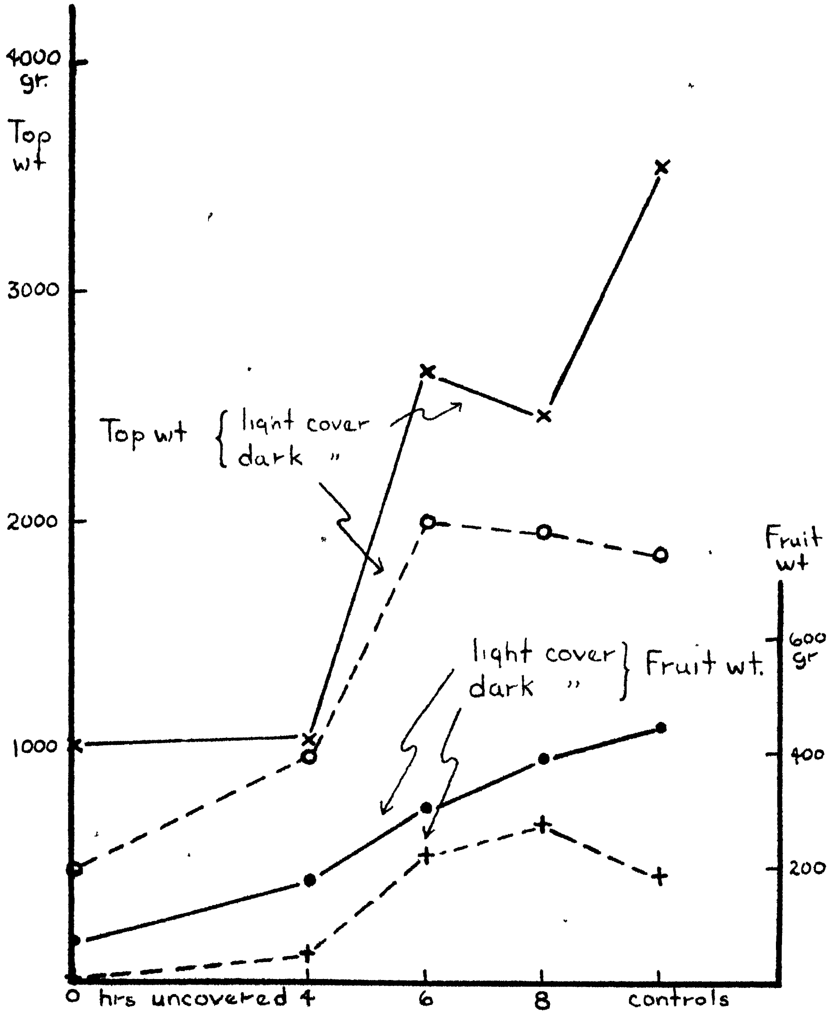


FIG. 3. Wet weight (in grams per 18 plants) of tomato plants and fruits grown with partial shade in the field in late autumn. At left: plants kept covered 24 hours per day. At right: plants never covered. The others covered except for 4, 6 or 8 hours daily, either with single or with double cover of muslin, decreasing light to 30 per cent or 10 per cent of normal daylight.

tinuously covered and uncovered plants. With the dark cover, transmitting only 10 per cent of the daylight, a fairly clear response was found. The top and fruit weights of the 6- and 8-hour exposed plants were actually greater than those of the permanently uncovered plants. The differences were much smaller than in the first experiment, which can be accounted for: (a) reduced light intensity is not as effective as complete darkness, and (b) the main growth of these plants was made in November and December with short days, so that a covering effect would be restricted to only three hours in the late afternoon, whereas in the first experiment the main growth period was May-June, with a 5 to 6 hours effective period.

The Pearson and the Marglobe tomatoes showed the most pronounced effect of shading on vegetative growth; even in the light shade they responded; the Illinois T19 showed the greatest response in fruiting. From Table II it can be seen that whereas the vegetative development of the tomato varieties did not show great differences, their fruiting was very different according to their response to temperature (2).

TABLE II—FRESH WEIGHT OF FRUITS AND TOPS OF TOMATOES GROWN UNDER SHADE OR IN FULL DAYLIGHT, GROUPED ACCORDING TO VARIETY (EACH FIGURE THE TOTAL OF THIRTY PLANTS)

Variety	No. of Growing Fruits	Weight of Growing Fruits (Grams)	Weight of Tops Exclusive of Fruits (Grams)	Fruit Weight as Percentage of Top Weight
Beefsteak	2	13	3,130	0.4
San Jose Canner	3	45	3,797	1.2
Marglobe	5	41	2,697	1.5
Pearson	16	269	3,008	8.9
Earliana	39	421	2,925	14.4
Illinois T19	56	1,314	2,471	53.1

Several other experiments were performed with the covering of tomatoes. Those covered in the afternoon from 14:00 on showed a better vegetative growth and much earlier fruiting during the months of February-June; in midwinter growth was so slow in both covered and control groups that no practical effects were achieved.

Thermographs were placed under the covers and in the open next to the covered plots. There was sufficient air circulation under the covers (along the edges of the covers there always were slits) so that there was less than 1 degree C temperature difference between covered and non-covered plots. The responses which were obtained can therefore not be attributed to merely differences in temperature. We also know that tomatoes, eggplants and beans are photoperiodically indifferent, so that the reduction in photoperiod caused by the covering can not be used to account for the greatly increased growth and fruit set.

DISCUSSION

There are several different responses of plants to shading in the afternoon. The most obvious responses are those, in which the yield is decreased by shading (lettuce, cauliflower) and where yield is greatly increased (tomato, eggplant). In the latter plants it is obvious that the photosynthetic process is *not* limiting growth. On the contrary, the photosynthetic efficiency seemed increased by shortening the photoperiod. This of course is not the case, but the photosynthetic products are used more efficiently. In the tomato it has been shown that the processes which control growth occur in darkness, during night (1). Therefore the conditions during darkness determine how much photosynthetic products are transformed into plant matter. Since there is no storage of food in a tomato plant, only as much photosynthesis occurs as is necessary to replenish what has been used during night, and therefore the night conditions determine apparent photosynthetic efficiency. When during winter and spring night temperatures are too low for optimal growth, only a fraction of the manufactured food is used. Utilizing part of the afternoon for the night processes by surrounding the plants with black covers does not decrease photosynthesis, but adds a period of darkness at more optimal nyctotemperature to the night.

It is obvious that the higher the optimal nyctotemperature of a plant is, the more it will be benefited by afternoon covering. Tomatoes and eggplant are both vegetables which thrive only under fairly warm climatic conditions. The tomato has optimal nyctotemperatures of 13 to 18 degrees C. Lettuce on the other hand has optimal nyctotemperatures of 8 to 13 degrees C (unpublished data). Therefore lettuce could be expected to grow in Pasadena at an almost optimal rate during spring, and actually covering did not improve yield. Members of the cabbage family seem to be coolweather plants, and consequently cauliflower was not benefited by covering. Table III shows the actual temperatures prevailing during the two experiments which were described.

TABLE III—MEAN OF THE MAXIMUM AND MINIMUM TEMPERATURES IN DEGREE CENTIGRADE (APRIL 17 TO JULY 5 AND OCTOBER 1 TO DECEMBER 31, 1944)

Date	Maximum	Minimum	Date	Maximum	Minimum
Apr 17–23	21.3	8.4	Oct 1–7	26.9	10.7
Apr 24–30	18.4	8.6	Oct 8–14	24.9	10.7
May 1–7	26.2	11.3	Oct 15–21	25.3	10.8
May 8–14	22.1	10.4	Oct 22–28	26.9	12.5
May 15–21	20.9	10.5	Oct 29–Nov 2	21.7	12.9
May 22–28	21.4	11.9	Nov 10–16	15.9	9.3
May 29–Jun 5	22.0	12.6	Nov 17–23	21.9	8.2
Jun 13–19	23.0	10.9	Nov 24–31	20.9	7.7
Jun 20–26	22.8	11.0	Dec 1–7	21.4	9.4
Jun 27 to Jul 5	28.2	12.4	Dec 8–14	23.6	9.7
			Dec 15–21	22.3	9.8
			Dec 22–31	18.3	7.3

It is likely that a practical method of covering could be worked out, which would make it possible to grow crops in the open which normally can be cultivated in glasshouses, or to get hot-weather crops started in cool weather.

It seems worth while to study the responses of many more plants to various types and periods of covering. For instance, it should be determined whether the hotcap method of starting heat-loving plants in spring is so effective due to the shading in the afternoon. Realization of these shading effects may also rationalize planting schedules in the field. When windrows of trees are running N-S through a field, tomatoes, eggplants and other of the same type should be planted in spring along the E side of the windrows, where they receive afternoon shade. Beets or cabbage could be planted along the W side of the windrows, since they are not likely to be affected by shading at any particular time. It also is possible that the old saying of gardeners, that the morning sun is most beneficial for many plants, has to be restated as: afternoon shade is beneficial.

This preliminary study indicates, how important it is to have a complete knowledge of the responses of vegetables to each of the many enviromental factors, and to have an understanding of the reasons for these responses.

SUMMARY

Several vegetables were grown in plots which could be covered with black paper or with cloth. Each day these plants were covered for a definite length of time. It turned out that the yield of lettuce and cauliflower was decreased by any length and type of covering, whereas tomatoes and eggplants were strongly stimulated in growth and fruiting by daily covering from 14:00 until next morning 7:00. Other plants like beets and celery were little affected. The decrease in light preferably should be to 10 per cent or less of normal daylight.

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Some Physical Responses of Pimiento Plants to Creosote When Used for Treating Timbers in Steam-Heated Hot Beds

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The use of creosote as a wood preservative and termite *(Termes flavipes)* repellent has long been suggested as a worthwhile practice. Little appears to have been published, however, on the use of creosote for treating timbers in steam-heated hot beds, and its resultant effect on seed germination and subsequent growth of the young plants.

During the winter months of 1941–42 Pomona Products Company constructed thirty new hot beds, each 12 feet wide and 150 feet long, for growing pimiento (*Capsicum frutescens* L.) plants (Fig. 1). These beds were equipped with three suspended lines of 1¼-inch pipe through which steam for heating was furnished by a 100-horsepower boiler. In all beds the heating pipes were placed at least 8 inches above the surface of the soil, and the side ones 18 inches away from the walls.

On June 12, 1942 all timbers of fifteen of the hot beds were painted with undiluted creosote as a precaution against decay, while the remaining fifteen beds were left untreated due to a lack of labor for applying the material. Grass and weeds in the beds were kept under control by hoeing during the late summer and fall. During the first two weeks in February the beds were spaded up, fertilized, and leveled with hand rakes. After remaining in this condition for several days they were planted to pimiento seed in 4-inch rows for the first time on February 20, 1943. After the planting was completed the beds were watered by the overhead sprinkler type of irrigation and covered with medium weight (56 threads to the inch) unbleached sheeting.

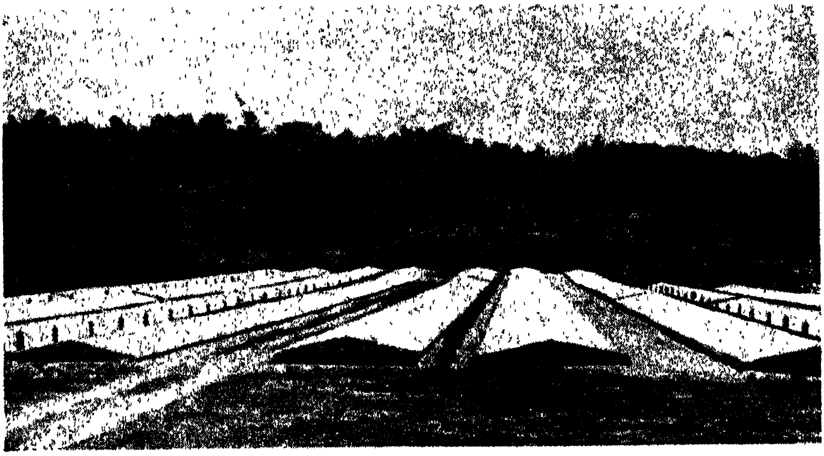

Fig. 1. View of some of the cloth covered hot beds showing overhead irrigation pipes between some of the beds, and heating plant in background.

FIG. 2. Section of a representative hot bed which did not have its timbers treated with creosote. Note uniform stand and size of plants.

Steam was turned on to raise the air temperature of the beds within the range of 80 to 90 degrees F. Since this temperature range has been found by the author to be the most optimum for both seed germination and early growth of young pimiento plants (unpublished data), the hot beds were maintained as nearly as possible within this temperature range for a period of four weeks. On sunshiny days, however, the temperature underneath the covers frequently ran up as high as 100 degrees F or above. Except for removing the covers to permit weeding and watering of the beds, they were kept closed during the whole of this period. Thermometers in the beds were read by slightly raising the covers at their immediate location.

Soon after the temperature of the beds had been raised to within the desired range, fumes of the creosote which had been used nine months previously for treating the timbers in some of the beds, could be readily detected by raising the covers. Within 21 days after planting all beds which had not had their timbers treated with creosote were up to a uniform stand. These plants grew off well (Fig. 2) and maintained a healthy green color for the duration of time they remained in the beds. Attention is called to the fact that as good a stand of plants was secured near the walls of these beds as in any other portion. While a fairly good stand of plants was secured in a strip which averaged 30 inches wide in the middle of the creosote-treated beds, it became poorer and poorer as the walls of the beds were approached. In fact, the creosote fumes were so toxic that no plants came up within 4 inches of the treated walls (Fig. 3). Of the plants that came up within 36 to 48 inches of the walls many of them died. The plants that survived in this area became severely stunted and failed to reach a transplantable size, even after they were given repeated applications of supplementary nitrogen and ample water for good growth.

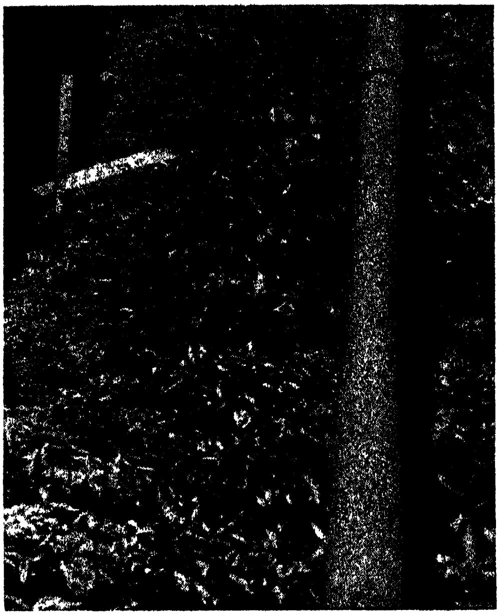

FIG. 3. Section of a representative hot bed which had its timbers treated with creosote nine months prior to planting the seed. Note unevenness of stand, size of plants present, and lack of plants near bed walls.

The first visible indications of creosote injury to young pimiento plants manifested itself by causing the leaves to turn grayish and roll up. This leaf roll is caused by a curling upward and inward of the marginal area to the extent that a portion of the lower surface oftentimes becomes the upper surface. The cotyledons of young plants are especially susceptible to this response as is exemplified in Fig. 4B; and Fig. 4A shows normal plants taken from adjacent hot beds which did not have their timbers treated with creosote. The injury was apparent within five days after the plants came up. These findings are well in agreement with those reported by Jones (1) who has shown the same type of injury to exist with plants of tobacco, tomato, lettuce and cabbage when grown in creosoted boxes under greenhouse conditions.

Upon examination of the roots of some of the badly injured plants near the creosote-treated walls, it was found that many of them had turned dark as if they, too, had been injured. To try and throw more light on what appeared to be creosote injury to plant parts underneath the soil, a sizeable number of seed which were planted near the treated walls, but failed to come up, were removed from the soil, washed, and examined. As evidenced by dark colored sprouts of various lengths on many of the seed, early growth of the young plants had started, but entirely ceased due to creosote injury before the young plants emerged through the surface of the soil.

In the work of Jones, as cited above, it was reported that creosoted wood when completely buried underneath the soil failed to produce any injury to plants known to be susceptible to airborne fumes. In all probability this was caused by the fact that no part of the buried wood was exposed to the action of the sun or any type of artificial heat, thus the temperature surrounding it never reached a point high enough to bring about volatilization of the material.

It was possible during the summer of 1943 to check further on the toxicity of creosote fumes to young plants when the timbers of four

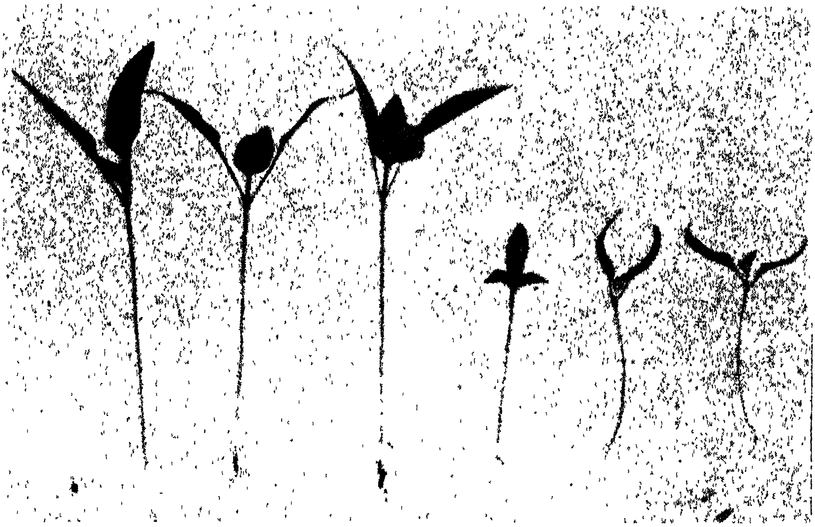

FIG. 4. (A) Normal Pimiento plants; (B) Creosote-injured plants. All plants pulled 10 days after emerging from soil.

more beds were treated. The entire 30 beds were planted to cow peas (*Vigna sinensis*) on July 7. Within eight days after planting there was a good stand of plants on all beds except the four which only a short time prior had had their timbers treated with creosote. This being in the summer time no covers were kept over the beds or no steam heat was used, yet the heat from the sun was sufficient to volatilize the creosote and produce the conventional type of injury to the young cow pea plants.

After the first season's work with growing pimiento plants in covered hot beds it was thought that a lack of ventilation may have augmented the seriousness of the creosote injury. However, since the injury to the pea plants grown in the open was in every respect as bad as that produced on pimiento plants grown under cover this undoubtedly must not be much of a contributing factor.

The cow peas were cut and turned under as a cover crop on September 26, 1943. All hot beds were again planted to pimiento seed on February 23, 1944. Without an exception, the stand of plants, condition of germination near the treated bed walls, and appearance of the young plants on the four beds that had their timbers treated with creosote during the previous summer, and in which many pea plants were injured and even killed, behaved precisely in the same manner as they did in other hot beds when planted to pimiento seed under the same conditions during the winter of 1943. On the other hand, as good stands of healthy plants were secured with no injury resulting on beds which had their timbers treated with creosote twelve months in advance of planting, as were obtained on untreated beds.

SUMMARY

Pimiento plants grew normally in ordinary steam heated hot beds covered with medium weight unbleached sheeting. However, when the seed were planted within nine months in hot beds that had had their timbers treated with creosote the plants became injured. The symptoms of the trouble were: A check in plant growth, leaf discoloration, rolling of the leaves, defoliation, and in many cases death of the entire plant.

Creosote fumes which penetrated the soil near the treated bed walls caused the roots of many plants to turn dark and finally die.

From this work it would appear that a lack of ventilation in the hot beds is not much of a contributing factor to the seriousness of creosote injury to young plants. Typical injury was produced on young cow pea plants which were grown in uncovered beds during mid summer that had had their timbers treated with creosote only a short time before the seed were planted.

A relatively high air temperature is essential for the volatilization of the toxic agent in creosote.

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A Semi-Quantitative Quick-Test for Determining Quinine in Cinchona Bark

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IN selecting a method for evaluating Cinchona bark, due consideration should be given to the kind of information required and its application. For example, a grower or plant propagator desiring to know the quinine content of his Cinchona bark will require a less accurate and simpler process than a manufacturer buying large quantities of crude bark for the extraction of quinine. Most analytical methods require elaborate expensive apparatus, and, in addition, considerable time and skill in extracting and determining the quinine of the bark. They require also relatively large samples of 10 to 20 grams. Thus, there is a definite need for a simple quick method of estimating quinine in small samples that can be carried out with a minimum of apparatus and equipment.

Among the various qualitative color tests given by quinine, the thalleioquin reaction seemed to offer the best prospect of being developed into a semi-quantitative method. Many modifications of the test have been made to increase its sensitivity since it was first discovered by Meeson (3) in 1835. More recently Wagg (4) proposed the thalleioquin reaction as a qualitative test for Cinchona and presented data showing some of the conditions affecting the reaction. On the basis of this and other reports the present investigation was undertaken.

EXPERIMENTAL

The thalleioquin reaction (green color or precipitate) is produced when a solution of quinine, rendered as nearly neutral as possible, is treated first with chlorine or bromine and then excess ammonia is added. It has been shown (4) that the kind and concentration of reagents, the acidity of the test solution and the concentration of the quinine solution influence the formation of the green color. It was the object of this investigation to find an optimum combination of these variables that would indicate by color intensity the approximate concentration of quinine.

Several of the chlorine and bromine reagents including potassium bromate and chlorinated lime were tested for their suitability in giving the thalleioquin reaction. Of the various reagents tried the most satisfactory was a freshly prepared 20 per cent saturated solution of bromine water. This was easily prepared by having a saturated solution of bromine on hand and making the appropriate dilutions from it as needed. It has been observed by Léger (1) and others that the amount of ammonia is much less important than the quantity of bromine. The main function of the ammonia is to render the solution alkaline. A 10 per cent solution of ammonia was found to be suitable for this purpose and 1 milliliter of this reagent was used in all tests.

In developing the method a series of 12 graded stock solutions of quinine sulfate was used. The concentration of the stock solutions ranged from 2 to 24 milligrams per cubic centimeter. These stock solutions were made up in this concentration so that 2 mililiters of each would represent the equivalent amount of quinine sulfate that would be obtained from 0.4 gram samples of Cinchona bark containing 1 to 12 per cent quinine sulfate. The next step was to find the optimum dilution at which these solutions gave the best gradation of color intensity with various volumes of the bromine reagent. A good gradation of green color was obtained by diluting 2 milliliters of each stock solution to 50 milliliters in a 50 milliliter volumetric flask and using 5 milliliter portions of this for the test.

It has been shown by Wagg (4) that the development of the green color is prevented if the solution to be tested is too acid, and he suggests the use of 10 per cent NH_4OH to neutralize the acid. However, the presence of small amounts of NH_3 in the test solution prevents the formation of a green color and it is necessary to remove any excess ammonia by boiling. Since this operation is rather delicate and much care must be used in neutralizing the acid and removing the ammonia, it was felt that the method would be greatly facilitated if this step could be omitted. Accordingly, various concentrations of acid were tested in making up the stock solutions until one was found which would dissolve the quinine standards and at the same time not render the solution sufficiently acid as to materially interfere with the development of the green color. It was found that 1N H_2SO_4 could be used to make up the stock solutions of quinine sulfate and when 2 milliliters of these solutions were diluted to 50 milliliters it was not necessary to neutralize them in order to develop the green color.

Different volumes of the 20 per cent saturated bromine solution were then added to 5 milliliters aliquots of the graded quinine sulfate solutions until a definite gradation of color intensity was obtained for a given series of concentrations with a given amount of the bromine reagent. In all tests 1 milliliter of the 10 per cent NH_4OH was used following the bromine to render the test solution alkaline and to develop the color.

Table I shows the relative green color intensity obtained with given volumes of bromine in the graded quinine solutions.

In applying the test to Cinchona bark it was necessary to first extract the quinine quantitatively in order that a solution of quinine sulfate could be prepared and color developed and compared with that of the standard solutions. The usual extraction procedure for Cinchona is tedious and time consuming and therefore not suitable for a rapid method. It was necessary to find some way to speed up and simplify this part of the procedure. The extraction technique described by Loustalot and Pagán (2) with a few modifications has been found satisfactory for this purpose and is described below.

Data presented in Table II show the quinine sulfate content of several samples of Cinchona bark estimated by the thalleioquin method compared with that found by the official quantitative procedure. It will be seen from these data that the amount of quinine sulfate can be estimated to within 1 per cent of the amount present. It should be noted that the method also includes as quinine any quinidine, hydro-

TABLE I—RELATIVE COLOR DIFFERENCES OBTAINED WITH FIVE MILLILITER PORTIONS OF DILUTED STANDARD QUININE SULFATE SOLUTIONS TREATED WITH DIFFERENT VOLUMES OF TWENTY PER CENT SATURATED BROMINE WATER

Concentration of Diluted Quinine Sulfate Standards (Ppm)	Per Cent Quinine Sulfate Equivalent in 0.4 Gram Sample of Bark (Per Cent)	½ Ml* Bromine	1 Ml* Bromine	2 Ml Bromine
80	1	Very light color	Colorless	No color
160	2	Pale green color	Very slight color	No color
240	3	Light green color	Pale green	Very pale green
320	4	Somewhat darker than 3	Light green	Very pale green
400	5	Darker than 4	Somewhat greener than 4	Same as 4
480	6	Same as 5	Emerald green	Same as 4
560	7	Same as 5	Somewhat darker than 6	Pale green
640	8	Same as 5	About same as 7	Light green
720	9	Same as 5	About same as 7	Green
800	10	Same as 5	About same as 7	Dark green
880	11	Same as 5	About same as 7	Very dark
960	12	Same as 5	About same as 7	Black green

*One milliliter 10 per cent NH_4OH used in all tests.

TABLE II—QUININE SULFATE CONTENT OF CINCHONA BARK FOUND BY THALLEIOQUIN METHOD COMPARED WITH THAT FOUND BY OFFICIAL METHOD

Sample	Quinine Sulfate by Official Method (Per Cent)	Quinidine Sulfate by Official Method (Per Cent)	Quinine and Quinidine Sulfate by Official Method (Per Cent)	Quinine Sulfate by Thalleioquin* Method (Per Cent)	Differenc (Per Cent
1	7.8	—	7.8	8.5	+0.7
2	8.3	—	8.3	8.5	+0.2
3	7.7	—	7.7	8.0	+0.3
4	5.1	0.1	5.2	5.5	+0.3
5	5.0	0.1	5.1	5.5	+0.4
6	2.1	—	2.1	2.5	+0.4
7	1.4	—	1.4	1.5	+0.1
8	1.9	0.2	2.1	2.5	+0.4
9	3.8	—	3.8	4.5	+0.7
10	3.8	—	3.8	4.0	+0.2

*Includes any quinidine present.

quinine or hydroquinidine present since these substances also give the thalleioquin reaction. However, these alkaloids are somewhat similar to quinine in their physiological use and therefore no serious error is introduced by their inclusion as anti-malarial substances. Also the presence, if any, of these substances in Cinchona bark is usually small.

The method as finally developed was as follows:

1. *Extraction:*—Two grams of powdered (100 mesh) bark is weighed into a 100 milliliter beaker. Half a gram of calcium oxide measured approximately in a spoon is added with enough water (5 to 10 milliliters) to make a smooth homogeneous paste. After standing for 10 minutes, the paste is transferred to a 200 milliliter volumetric flask with 100 to 150 milliliters of ethyl alcohol. The alcoholic bark suspension is well shaken and allowed to stand an hour or longer with occasional shaking after which it is made up to volume with alcohol, shaken and filtered through fast filter paper. An aliquot of the extract, representing 0.4 grams of Cinchona bark, is pipetted into a 150 milliliter

beaker and evaporated to dryness on a steam bath. Two milliliters of 1N H_2SO_4 is added to the residue and with the aid of a rubber policeman the residue is dissolved and transferred into a 50 milliliter volumetric flask with water and made to volume. The solution is then filtered and 5 milliliter portions of the filtrate used for the thalleioquin reaction.

2. *Preparation of Standard Stock Solutions of Quinine Sulfate:*—Twelve stock solutions of quinine sulfate are prepared by dissolving in 1N.H_2SO_4 U. S. P. XI quinine sulfate in amounts ranging from 2 to 24 milligrams per milliliter. These stock solutions will keep a long time in tightly stoppered black bottles. The bottles should be numbered from 1 to 12 to correspond to the relative percentage of quinine sulfate. Two milliliters of each stock solution represents the amount of quinine sulfate equivalent that would be found in 0.4 gram samples of cinchona bark ranging from 1 to 12 per cent, respectively.

3. *Estimation of Quinine by Thalleioquin Reaction:*—Two milliliters of each stock solution are pipetted into 50 milliliter volumetric flasks and made to volume with distilled water. Five milliliter aliquots of the diluted stock solutions are transferred to test tubes marked from 1 to 12 corresponding to the relative per cent of quinine sulfate represented.

One milliliter of the freshly prepared 20 per cent saturated bromine is added from a burette to each test tube numbered from 1 to 7. The tubes are well shaken and 1 milliliter of 10 per cent NH_4OH solution is added. A good gradation in green color intensity develops ranging from almost colorless in test tube No. 1 to emerald green in test tube No. 7. Five milliliter portion of the unknown cinchona bark extract prepared as described above is treated the same as the standards. The color developed is compared with that of the standard solutions. If the color of the unknown solution can be matched in the range between 3 and 6 per cent no further test is necessary and the quinine content is estimated to the nearest 0.5 per cent. If the color developed in the unknown indicates that the per cent quinine sulfate is about 3 per cent or less, the test is repeated with a fresh 5 milliliter portion of the unknown and fresh standards 1 to 3, this time using ½ milliliter of bromine instead of 1 milliliter. However, if the color of the unknown in the first test is as intense as that of standard solution No. 7, the test is repeated using 2 milliliters of bromine reagent and comparing with standard 7 to 12 treated in the same way (Table I).

SUMMARY

A simple rapid semi-quantitative method for estimating quinine content of Cinchona bark is described. The method has the advantage of requiring a minimum of equipment and reagent and only small samples of bark (2 grams). It has the disadvantage of giving only an approximation of the quinine content, that is, within 1 per cent of the amount actually present and it includes as quinine any quinidine or related substances that give the thalleioquin reaction. The method is most suitable as a quick "screening" test for use by plant breeders or by Cinchona growers in culling their low quinine yielding strains.

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The Number of Vegetable Seeds per Unit Weight[1]

By GERMAINE D. SEELYE,[2] *Cornell University, Ithaca, N. Y.*

INTRODUCTION

THE variation in number of seeds per unit weight is of prime importance to seedsmen and to vegetable growers. It is important for its practical use and as a basis for further study of factors influencing differences in seed weight.

Variation in seed weight would make a considerable difference in recommendations for the quantity of seed required per acre or 100 feet. Growers often plant too much or too little seed due to the lack of adequate data. These studies have shown as much as 60 per cent variation in weight of seeds between two varieties. If the machine for sowing is not properly adjusted for size of seed, a poor stand is likely to result. This means that the stand may be too thick necessitating a costly job of thinning or loss from over-crowding. Or the stand may be too thin resulting in reduced yield with little or no reduction in cost per acre and thus with increased cost per unit of product harvested. This is even more important under present conditions when labor costs prohibit the old common practice of thinning even with carrots or beets as well as with many of our other vegetable crops. Even when thinning is practiced as with lettuce, the cost of the operation is greatly increased if the original stand is too thick. Stand is also an important factor governing quality and economy in seed beds where plants are grown for transplanting.

The amount of seed in a packet varies widely with different seed firms, sometimes by 50 per cent or more. The seedsman has access to little information regarding the amounts of seeds placed in packets by other companies nor has he adequate counts of seeds per unit of weight. Some companies use packaging machines which fill the packets automatically, based on weight or volume while others use simpler methods of weight or volume measures.

This study is concerned with the differential weights per 100 seeds of commercially grown vegetables in relation to kind, variety, strain, and year. This paper is merely an introduction to the problem and to the factors which might influence the differences.

REVIEW OF LITERATURE

Many studies concerning the longevity, the germination, and the factors affecting quality of vegetable seeds have been made whereas the differential weights of seed have been neglected. There is little

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[1] Paper No. 280. Department of Vegetable Crops, Cornell University, Ithaca, New York.

[2] The author wishes to thank Professor Paul Work of the Department of Vegetable Crops, Cornell University, for his helpful suggestions and advice, to Mrs. Olive Wilkinson who typed the paper, and to the G. L. F. at Ithaca, New York and the Robson Seed Farms, Hall, New York for supplying the seeds used in this work.

TABLE I—VARIABILITY IN WEIGHT OF VEGETABLE SEEDS BY KINDS, VARIETIES AND YEARS

Variety and Source	Year*	Average Weight 100 Seeds (Grams)	Number of Seeds Per Ounce	Average No. Seeds Per Ounce	Varieties		Years	
					Odds 100 Seeds	L. D. 99:1	Odds 100 Seeds	L. D. 99:1
Beet								
Crosby Egyptian A	1942	1.24	2,286	2,531	—	—	—	—
Crosby Egyptian A	1943	0.92	3,082	—	—	—	—	—
Crosby Egyptian A	1944	1.20	2,363	—	—	—	—	—
Detroit A	1942	1.65	1,718	1,718	799:1†	0.0025 gram	799:1†	0.0025 gram
Detroit A	1943	1.56	1,817	—	—	—	—	—
Detroit A	1944	1.70	1,668	—	—	—	—	—
Early Wonder A	1942	1.47	1,929	1,890	—	—	—	—
Early Wonder A	1943	1.29	2,198	—	—	—	—	—
Early Wonder A	1944	1.74	1,629					
Carrot								
Long-Type Chantenay A	1942	0.15	18,900	22,323	—	—	—	—
Long-Type Chantenay A	1943	0.10	28,350	—	—	—	—	—
Long-Type Chantenay A	1944	0.13	21,808	—	799:1†	0.0194 gram	799:1†	0.024 gram
Imperator A	1942	0.16	17,719	19,286	—	—	—	—
Imperator A	1943	0.14	20,250	—	—	—	—	—
Imperator A	1944	0.14	20,250					
Onion								
Riverside Sweet Spanish A	1942	0.39	7,269	7,326	—	—	—	—
Riverside Sweet Spanish A	1943	0.38	7,461	—	—	—	—	—
Riverside Sweet Spanish A	1944	0.39	7,269	—	—	—	—	—
Yellow Globe Danvers A	1942	0.39	7,269	7,810	799:1†	—	799:1†	—
Yellow Globe Danvers A	1943	0.30	9,450	—	—	—	—	—
Yellow Globe Danvers A	1944	0.40	7,088	—	—	—	—	—
Michigan Yellow Globe B	1942	0.36	7,875	8,338	—	—	—	—
Michigan Yellow Globe B	1943	0.30	9,450	—	—	—	—	—
Michigan Yellow Globe B	1944	0.36	7,875	—	—	—	—	—
Lettuce								
Grand Rapids A	1942	0.13	21,808	21,808	—	—	—	—
Grand Rapids A	1943	0.13	21,808	—	—	—	—	—
Grand Rapids A	1944	0.13	21,808	—	—	—	—	—
Imperial No. 44 A	1942	0.12	23,625	23,049	799:1†	0.015 gram	—	—
Imperial No. 44 A	1943	0.12	23,625	—	—	—	—	—
Imperial No. 44 A	1944	0.13	21,808	—	—	—	—	—
Black Seeded Simpson A	1942	0.09	31,500	29,842	—	—	—	—
Black Seeded Simpson A	1943	0.10	28,350	—	—	—	—	—
Black Seeded Simpson A	1944	0.09	31,500	—	—	—	—	—

			Tomato					
John Baer C	1942	0.18	15,750	11,825	—	—	—	—
John Baer C	1943	0 24	11,825	—	—	—	—	—
John Baer C	1944	0.31	9,145	—	—	—	—	—
Marglobe C	1942	0.31	9,145	9.145	799:1†	0.007	No Sig.**	—
Marglobe C	1943	0.31	9,145	—	—	—	—	—
Marglobe C	1944	0.31	9,145	—	—	—	—	—
			Cucumber					
A & C D	1942	2.73	1,038	1,009	—	—	—	—
A & C D	1943	2.91	974	—	—	—	—	—
A & C D	1944	2.80	1,013	—	799:1†	0.06	No Sig.**	—
Early Fortune D	1942	2.74	1,035	1,062	—	—	—	—
Early Fortune D	1943	2.58	1 099	—	—	—	—	—
Early Fortune D	1944	2.71	1,046	—	—	—	—	—
			Snap Beans					
Bountiful E	1942	32.45	87	87	—	—	—	—
Bountiful E	1943	32.74	86	—	799:1†	1.58	No. Sig.**	—
Pencil Pod E	1942	42.35	67	69	—	—	—	—
Pencil Pod E	1943	40.34	70	—	—	—	—	—
			Sweet Corn					
Carmel Cross F	1942	23.24	122	124	—	—	—	—
Carmel Cross F	1943	24.63	115	—	—	—	—	—
Carmel Cross F	1944	20.66	137	—	—	—	—	—
Golden Bantam F	1942	25.63	111	117	—	—	—	—
Golden Bantam F	1943	24.58	115	—	—	—	—	—
Golden Bantam F	1944	22.62	125	—	799:1†	0.53 gram	799:1†	0.45 gram
Golden Cross Bantam F	1942	22.63	125	134	—	—	—	—
Golden Cross Bantam F	1943	20.03	142	—	—	—	—	—
Golden Cross Bantam F	1944	20.89	136	—	—	—	—	—
Marcross F	1942	23.71	120	116	—	—	—	—
Marcross F	1943	25.14	113	—	—	—	—	—
Marcross F	1944	23.97	118	—	—	—	—	—

*Year given is the year the seedsmen offered the seed for sale.
**Not significant.
†Significant at odds 99:1.

experimental evidence available on this subject. Watts and Watts (4), Cox and Starr (2), and Bailey (1) and many others have published tables containing the number of seeds per ounce but the data varied widely and the origin of the data was not mentioned. Most authors have simply copied older tables.

Lloyd (3) compiled a table from data obtained by actual weighings of the seed. A number of varieties of the common vegetables were weighed and large differences in the number of seeds per ounce of different varieties of the same kind of vegetable were noted. Wilde (5) made actual weighings of the seeds of a number of varieties of several commonly grown vegetables and also noted wide differences. Wilde's data differed considerably from Lloyd's. This was partly due to the different varieties used. The varieties commonly used are changing continuously. Work (6) compiled a table using data of several workers. Consequently his table is more comprehensive.

The reliability of these data is questionable since either small samples were used or there was no statement explaining the number of samples used. The comparison of these tables demonstrates the differences in results obtained by different workers with different materials, and under different conditions.

PROCEDURE

Samples of seeds of representative varieties of beet, carrot, celery, onion, radish, tomato, cucumber, lettuce, snap beans, sweet corn, spinach, and watermelon seeds were obtained from several seedsmen in the fall and winter of 1944–1945 and were kept at room temperature and average relative humidity in East Roberts Hall, Ithaca, New York until the determinations were made. The samples included two to four varieties of seeds produced in 2 or 3 different years. The same strains and lot numbers were used each year.

Counts were made at random using five replicates of 100 seeds from each sample. Weights of samples were taken immediately on a Torsion balance and averages were calculated to the nearest 100th of a gram. The error with the smaller seeds would have been less if the weighings had been made on an analytical balance. The number of seeds per ounce was then calculated from these data.

Analysis of variance was used to determine the mathematical significance of the differences in the number of seeds per ounce in Table I. Differences of 10 per cent in the count of seeds might be considered to be of practical significance in actual farm and garden operations.

RESULTS

Beet:—The difference in counts of seeds between the varieties of beet used was as much as 47 per cent and was significant at odds > 99: 1. The Crosby Egyptian variety had the greater number of seeds per ounce with Early Wonder and Detroit Dark Red varieties following respectively. The 1943 seeds of these three varieties had the larger number per ounce followed by the 1942 and the 1944 respectively. The differences between years showed 23 per cent variation and was significant at odds 99: 1. The average weight of the same strain of Detroit Dark Red beets grown by seedsmen at Hall, New York and in North Carolina differed by as much as 80 per cent as shown in Table II. This substantiates the evidence that environmental factors are important. The difference in strains is shown by the 17 per cent variation between the Detroit Dark Red beet samples of seedsman L and seedsman A. It should be noted that the weight of the samples are quite variable because of the fact that the beet seed ball is an inflorescence each containing from one to four or more seeds.

TABLE II—VARIABILITY OF VEGETABLE SEEDS BY SOURCES

Variety and Source	Year	Average Weight in Grams Per 100 Seeds	Number Seeds Per Ounce	Per Cent of Range
Beet				
Detroit (L)	1944	1.46	1,941	17
Detroit (A)	1944	1.70	1,668	—
Detroit S Carolina (J)	1945	1.22	2,324	80
Detroit Hall, N Y (J)	1945	2.10	1,350	—
Cucumber				
A & C (C)	1943	2.80	1,013	4
A & C (D)	1943	2.91	974	—
Tomato				
John Baer (I)	1943	0.36	7,875	50
John Baer (C)	1943	0.24	11,825	—
Lettuce				
Black Seeded Simpson (C)	1944	0.15	18,900	55
Black Seeded Simpson (A)	1944	0.09	31,500	—
Onion				
Sweet Spanish (B)	1944	0.34	8,339	15
Sweet Spanish (A)	1944	0.39	7,269	—

Carrot:—The difference between varieties in number of seeds (fruits) was of practical significance with 16 per cent variation and of mathematical significance at odds 99: 1. The Long Type Chantenay variety had a greater count of seeds per ounce than did the Imperator variety. The variations between years was as much as 31 per cent and was significant at odds 99: 1.

Onion:—As much as 13 per cent variation was shown by the varieties and this difference was significant at odds 99: 1. The Michigan Yellow Globe variety had the greatest number of seeds per ounce followed by Yellow Globe Danvers and Riverside Sweet Spanish respectively. The difference between years was significant at odds 99: 1 and showed as much as 18 per cent variation. In Table II, a difference of 15 per cent was shown between samples of the Sweet Spanish variety grown by seedsman B and seedsman A.

Lettuce:—Even though lettuce seed (actually a fruit) is small and appears uniform, there was as much variation as 37 per cent between the varieties used and the difference was significant at odds 99: 1. The rate of seeding is important with lettuce. The Black Seeded

Simpson variety had the largest number of seeds per unit weight followed by the Imperial No. 44 and the Grand Rapids respectively. A variation of 55 per cent is shown in Table II between strains of Black Seeded Simpson lettuce seed grown by seedsman C and seedsman A. It is better to use an analytical balance when measuring lettuce seeds because of the minute size.

Tomato:—The variation between varieties used was of practical significance with 29 per cent variation and of mathematical significance at odds 99: 1. The John Baer variety had more seeds per ounce than the Marglobe variety. The difference between years was not significant. However, a variation of 50 per cent was noted between strains of John Baer grown by seedsman I and seedsman C as shown in Table II.

Cucumber:—Although the difference between varieties was mathematically significant at odds 99: 1, this difference of 4.5 per cent is not of practical importance. The difference in years was not significant and the difference between strains of A & C variety in Table II was not significant.

Snap Bean:—The Bountiful variety had 27 per cent more seeds per ounce than the Pencil Pod Black Wax variety and this difference was significant at odds 99: 1. Other varieties would show wider differences and the factor of seed cost per acre as well as influence on stand becomes important. The difference between years was not significant.

Sweet Corn:—Even though the varieties chosen are not considered to differ greatly in weight or size, as much as 16 per cent variation was shown. The difference between varieties was significant at odds 99: 1. The Golden Cross variety had the greatest number of seeds per ounce followed by Carmelcross, Golden Bantam and Marcross respectively. The variation in years was mathematically significant. Because of such wide variation, a seedsman in Hall, New York has already found it advantageous to include count of seeds per ounce of the sweet corn varieties in his seed catalogue.

DISCUSSION

The effect of environmental conditions on the weight and size of seed was shown by the decrease in the number of seeds per ounce of the 1943 samples of the beets, carrots, and onions, in Table I as compared with those grown in 1942 and 1944. All samples were obtained from the same seed company. This variation, noticeable in numerous varieties and kinds obtained from the same seed company, probably shows the effect of some limiting environmental condition in 1943. This suggests the desirability of research to reveal the influence of seed production conditions upon size of seed as well as upon viability.

The data here presented are fragmentary, merely demonstrating some of the wide variations in seed size that are to be expected. Many more counts including other kinds, varieties, years and conditions of growth would be required to establish an adequate table of seed counts per ounce.

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The Influence of Nitrogen Nutrition on Onion Seed Production in the Greenhouse

By Neil W. Stuart and Dorothy M. Griffin, *U. S. Department of Agriculture, Beltsville, Md.*

OBJECTIVES in the onion seed production study were two-fold: first, to develop and evaluate the effect of nutrient deficiencies on onion growth and seed production (2), and second, to compare the effect on seed production of various combinations of nitrogen, phosphorus, and potassium in the nutrient solution.

Previous studies at the Plant Industry Station, Beltsville, Maryland, had shown that if onion seed is planted in the greenhouse in late summer and the plants attain sufficient size and are exposed to cool temperatures during the winter, bolting occurs in certain varieties in early spring before the longer photoperiod and higher temperature cause bulbing (1). In order to speed up the breeding program this seed-to-seed method has been used in the onion breeding investigations here at Beltsville for a number of years, especially with the varieties Yellow Bermuda, Crystal Wax, and Creole.

In the present study seed of a single-bulb selection of the Yellow Bermuda variety, designated Yellow Bermuda 986, obtained from H. A. Jones, was planted in 2-inch pots containing Haydite (sintered shale) on September 1, 1943. The pots were plunged in Haydite and watered with a complete nutrient solution until November 10. At that date plants selected for uniformity were planted in 2 concrete greenhouse benches comprising a total of 18 sections, each 8 feet long, 57 inches wide, and 7 inches deep. Eight sections in one bench were filled with "F" or fine Haydite and eight in the other with "B" or medium Haydite. Each section was provided with an individual nutrient solution tank equipped for automatic subirrigation. The remaining section in each bench contained soil composed of 2 parts composted soil, 2 parts sand, 1 part manure, and 1 part muck and was planted with seedlings started in soil. These plants were top-watered and received no additional fertilizer applications during their growth. Seventy-two plants were set in each section. Each of the Haydite sections in a bench received a different nutrient solution, the arrangement being factorial with 2 levels each of nitrogen, phosphorus, and potassium (Table 1). The solutions were added to the tanks on November 17 and the beds subirrigated daily thereafter. At the end of each 2-week period samples of the solutions were taken for analysis, the remainder discarded, the

TABLE I—INITIAL COMPOSITION OF NUTRIENT SOLUTIONS APPLIED TO ONIONS GROWN IN HAYDITE, EXPRESSED AS PARTS PER MILLION.*

Level	Nitrogen		Phosphorus	Potassium
Level	Nitrate N	Ammonium N	Level P	Level K
N_1	10	3	P_1 3	K_1 19
N_2	50	15	P_2 15	K_2 95

*Each solution also contained (as ppm) Ca 71, Mg 24, Fe 2, Mn 1.5, B 0.5, Zn 0.15, Cu 0.06, and 1 ml per liter of 0.1 N H_2SO_4.

beds flushed with water, and a new solution supplied. The volume of solution was 170 liters per section of "F" Haydite and 208 liters per section of "B" Haydite. Use of a larger volume on the fine Haydite would have flooded the surface and encouraged the growth of Botrytis. The respective volumes were maintained by addition of tap water as needed.

Nitrate nitrogen was determined photometrically by the phenoldisulfonic acid method. Ammonium nitrogen in the solution was all absorbed or nitrified during the 2-week periods. The absorption of nitrate from the solutions is shown in Fig. 1. Each value represents the mean of determinations from the 8 solutions at each of the nitrogen levels, made just before renewal. At the lower level (N_1) nearly all of the nitrogen was absorbed from the solutions in each 2-week period during January, February, and March. The plants were obviously nitrogen deficient. The first flower stalks were visible on March 17. On April 6 the initial nitrogen level was increased from 13 to 32.5 ppm. Nearly all of this amount was utilized in each of the 3 successive 2-week periods. Later as the seed ripened less nitrogen was absorbed.

At the higher level of nitrogen (N_2) the plants were very vegetative and produced large multiple bulbs but very few seed stalks. This condition resulted regardless of the level of potassium or phosphorus in the nutrient solution. The level of nitrogen in all of the N_2 solutions was reduced to 13 ppm on April 6. This amount was absorbed rather completely until June 1. As the bulbs ripened little more nitrogen was utilized.

The phosphorus remaining in the nutrient solutions at the end of each 2-week period was usually less than 1 ppm at the lower level (P_1) and 3 to 4 ppm at the higher level (P_2). In the K_1 solutions the potassium was usually lower than 5 ppm and in the K_2 solutions it ranged from 35 to 50 ppm at each analysis. The growth of the plants could not be associated with differences in phosphorus or potassium content of the solutions.

The first onion flowers opened May 3 and a hive of bees was placed in the greenhouse to assure pollination. When ripe the seed heads were dried, thrashed, and the seed cleaned and weighed as previously described (2). Yields from the various sections, shown in Fig. 2, were much greater from the low nitrogen than from the high nitrogen treatments regardless of the phosphorus or potassium content of the solutions. This was due to the fact that the former produced an average of 90 seed stalks per section containing 72 plants while the latter had only 21 seed stalks per section. The plants in soil had 42 seed stalks per 72 plants and produced intermediate yields of seed. In general there was little difference in seed yield between the two benches (grades of Haydite) for any one nutrient treatment. The one exception was the $N_2P_1K_1$ solution in the bench containing fine Haydite. Apparently the reduced amount of solution (170 liters) on this section favored the formation of more seed stalks than in the corresponding section of the other bench which received 208 liters of solution.

In harvesting the bulbs from the high nitrogen treatments it was observed that they were split into several crowns. This suggested that

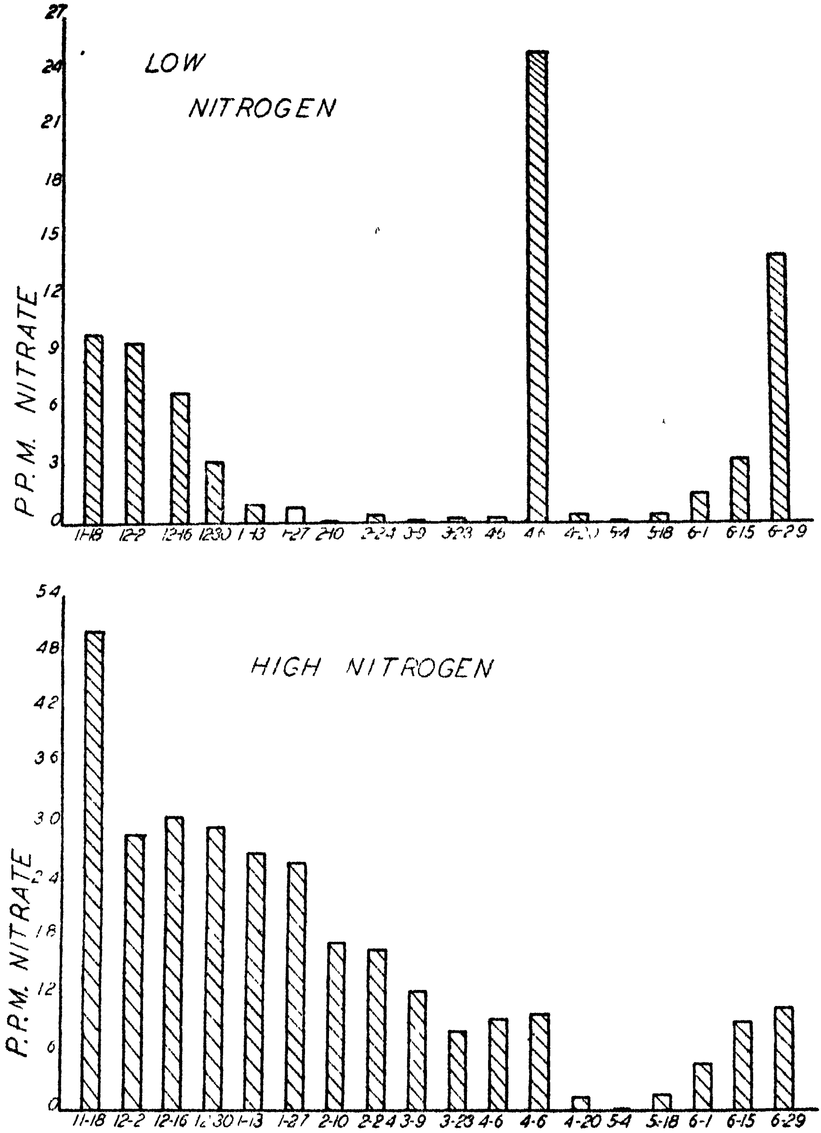

FIG. 1. Absorption of nitrogen by onions from nutrient solutions renewed at 2-week intervals during the growing season. Each column represents the average nitrate nitrogen content of solutions from 8 tanks just before renewal. Top, low nitrogen (10 p.p.m.); bottom, high nitrogen (50 p.p.m.).

if nitrogen were available for vigorous growth of the seedlings and was then limited during seed stalk initiation more seed stalks and seed should be produced. The following experiment was performed in order to test this hypothesis.

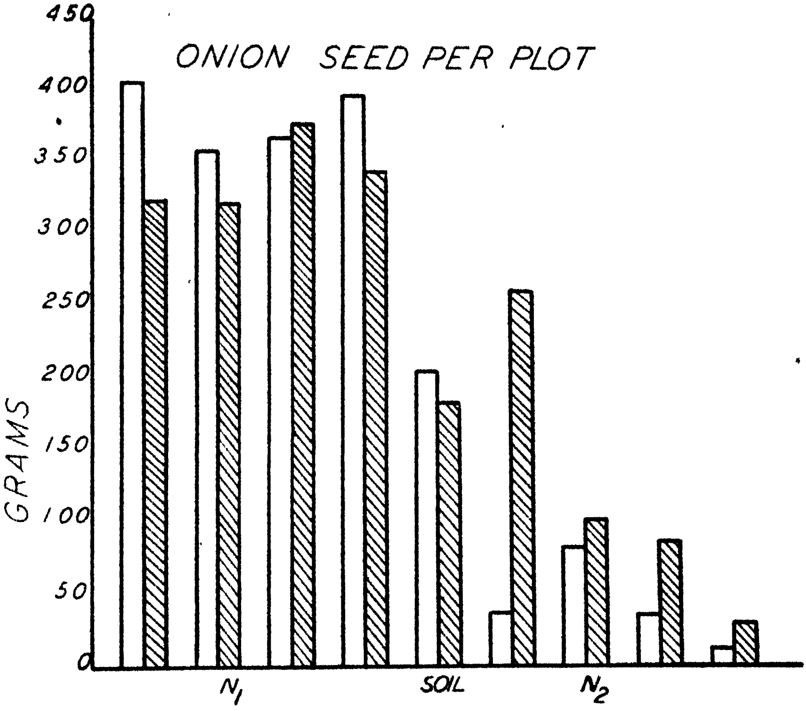

FIG. 2. Onion seed production per section of 72 plants. First column of each pair, yield from medium Haydite bench. Hatched column, yield from fine Haydite bench From left to right: $N_1P_1K_1$, $N_1P_2K_1$, $N_1P_1K_2$, $N_1P_2K_2$, soil, $N_2P_1K_1$, $N_2P_2K_1$, $N_2P_1K_2$, $N_2P_2K_2$.

Seed of Yellow Bermuda 986 was planted in 140 glazed crocks containing quartz sand on August 15, 1944. A complete nutrient solution low in nitrogen (21 ppm) was applied to one-half the plants and the same solution but containing 5 times as much nitrogen to the remaining plants twice per week until June 5. On November 1, 8 low nitrogen plants were shifted to high nitrogen and an equal number of the latter transferred to low nitrogen. The process was repeated on December 1, January 1, February 1, and March 1. Twice as many plants from each treatment were shifted in January and February and half of them were returned to their original nitrogen treatment after seed stalks were formed in March. Unusually high greenhouse temperatures in March were very unfavorable for onion seed production and yields were low. Plants given low nitrogen continuously were small and seldom divided to form more than one seed stalk, but they bolted uniformly. Plants on high nitrogen continuously were very vegetative and frequently bulbed instead of bolting. Average seed production from each of these two treatments was 2.8 grams per plant. Maximum seed yields were obtained when plants were grown on high nitrogen until January 1, transferred to low nitrogen for 2 months, and then restored to the high nitrogen. Such plants averaged 3.2 seed stalks and 7.5 grams of seed per plant. No other combination of nutrient conditions tested resulted in as high seed production per plant.

These results, while primarily applicable to onion seed production in the greenhouse in connection with onion breeding, are thought to have field application since much onion seed is produced under irrigation where nitrogen is easily applied and is immediately available.

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Lycopersicon Peruvianum as a Parent in the Development of High Ascorbic Acid Tomato Varieties

By A. F. Yeager and Helen J. Purinton, *New Hampshire Agricultural Experiment Station, Durham, N. H.*

In the spring of 1939, a successful cross was made between the Michigan State Forcing variety of tomato and *Lycopersicon peruvianum* PI 126946 (Fig. 1). This was after many attempts had been made and more than 200 fruits of normal size and shape produced by applying peruvianum pollen to Michigan State Forcing. This single seed is the only one the writer has ever succeeded in securing from such a cross. Others have since been reported as being more fortunate or else they have used embryo cultures. Pollen of the Peruvian tomato used on esculentum practically always causes fruit to set, develop normally, and reach normal size. The seeds, however, are abortive. As to why this particular seed set, no explanation is offered. Since there were no other small fruited tomatoes in the greenhouse from which pollen might have been transferred to Michigan State Forcing, and the F_1 plant showed unmistakable characteristics of Peruvian, there can be no doubt that a cross was secured. This F_1 plant was exceedingly vigorous and seemingly entirely fertile, with small, round, two to three locule orange-red fruits, averaging less than 10 grams each produced in long clusters. This F_1 plant was backcrossed to Early Chatham and from this in succeeding generations selections made. Selections from an F_2 population were also made for size, but all were too small to be of value. Some of the selections pro-

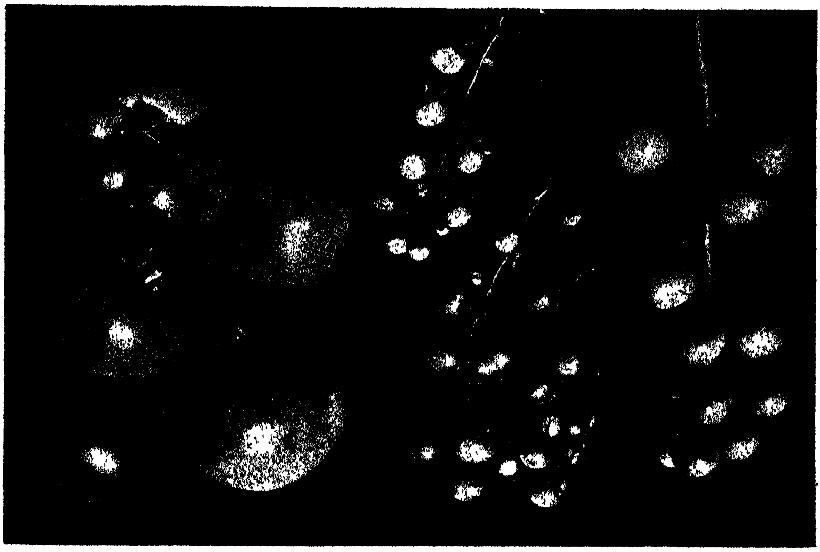

Fig. 1. Parents used. Left to right: Michigan State Forcing, Peruvian and F_1 Hybrid.

FIG. 2. High ascorbic acid selection from a back cross population.

duced a percentage of plants bearing seedless fruits but most of them were fertile. At the time these populations were grown, disease resistance was the objective and since it was not realized that Peruvian tomato was so high in ascorbic acid, no selections were made for this purpose (1). The seed was then laid away as an interesting but useless curiosity. When these selections were tested later to determine their ascorbic acid content, several were higher than normal but none of them proved to be outstanding. Because of the discovery that Peruvian tomato had such a high vitamin c'content, another F_2 population was grown in 1944 and an analysis of the fruits of each plant were made by the Department of Agricultural and Biological Chemistry. These showed a range of from 25 to 70 mg of ascorbic acid per 100 grams of fruit, with the mode at 35 mg, as compared to 15 mg for the average of several standard varieties and almost 75 mg for *Lycopersicon peruvianum* PI 126946 itself. While the highest ascorbic acid plants were mostly the smallest fruited, a few were among the larger fruited ones, still, however, weighing less than 20 grams per fruit. Several of these were selected, propagated asexually and crossed with New Hampshire Victor and Redskin. Certain of the plants from the Redskin hybrid showed an unusually high ascorbic acid content and a second generation from this cross was grown in the greenhouse during the spring of 1945, which gave fair sized, high testing fruits. Seeds from these selections were planted in the field in the summer of 1945, in plant progeny blocks. Analyses of fruits from the individual plants showed that some of these lines ran unusually high with a range between plants of from 43 to 67 milligrams of ascorbic acid, while standard varieties in no case ran above 26 mg, with the average at 19 mg. These fruits averaged 45 grams in weight, were red, and had good flesh and flavor. They were round to oval in shape with a beak (Fig. 2).

Another generation raised from these in the greenhouse during the winter of 1945–46, and analyzed for ascorbic acid, showed a range of from 35 to 46 mg of ascorbic acid at that time (February), which is twice as high as ordinary varieties analyzed at Durham in midsummer.

Some of these selections still show unusual vegetative vigor. One specimen in good soil made a plant 18 feet across and was still growing rapidly when frost killed the plant September 19, 1945. As they stand, these could hardly be called commercial but it seems evident that marketable types can be produced and still retain an ascorbic acid content far above any existing commercial sorts.

An F_1 cross between a high ascorbic acid line and New Hampshire Victor which fruited in the summer of 1945, had fruits of commercial size and shape and a mean ascorbic acid content of 39 milligrams, as contrasted to 19 milligrams for Comet as of that same date. They might, therefore, have value as parents in the production of F_1 hybrid tomatoes because of the partial dominance of high ascorbic acid content. Seed from the 1945 selections are available to any experimenter who may wish it.

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Pre-Emergence Sprays for Weeding Asparagus Seedlings

By JOHN SHAFER, JR., *New York State Agricultural Experiment Station, Geneva, N. Y.*

A large part of the expense involved in growing young asparagus plants lies in the hand weeding which must be done. Asparagus seed is slow to germinate, and the weeds get a head start on the asparagus.

At the suggestion of a near-by seedsman,[1] some selective weed sprays were tried on seedling asparagus in 1945. The materials used were 2,4–D, an oil of the dry cleaning type, three di-nitro compounds, and cyanamid dust. None of these gave satisfactory weed control without injuring the asparagus.

This past spring (1946) a few pre-emergence sprays were tried (1) consisting of a dry cleaning oil (Socony-Vacuum's Sovasol No. 5) or a di-nitro compound (Dow Chemical Company's G502). The oil was applied at two different times, a few days before the asparagus seedlings appeared; and the di-nitro compound was applied at the same times at two concentrations (1½ and 2 per cent). Each of the sprays was applied in sufficient quantity to wet all of the weed foliage. The various sprays were equally effective and provided weedless areas for the germinating asparagus seedlings. Thus, a large part of the initial hand weeding was eliminated.

No counts were made of the number of weeds killed, because the sprayed area was almost completely bare, in contrast to a plentiful weed cover on the control area. Because the stand of asparagus seedlings was variable in the unsprayed area, it was believed that counts of seedlings would not be of significance. Therefore, such counts were not made. However, none of the sprays caused any apparent injury to the asparagus.

This method of controlling weeds in an asparagus seedling bed looks sufficiently promising to warrant more extensive trials in the future. Probably any good weed-killing spray would be satisfactory for this pre-emergence spraying, provided only that a toxic residue is not left in the soil to injure the emerging asparagus seedlings.

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[1] We are indebted to the Robson Seed Farms, Hall, N. Y. for cooperation in this work.

Variations in the Dry Weight, Ascorbic Acid and Carotene Content of Collards, Broccoli and Carrots as Influenced by Geographical Location and Fertilizer Level

By Byron E. Janes, *University of Florida, Gainesville, Fla.*

The demand for high quality vegetables, coupled with the knowledge that vegetables are an important source of several vitamins, has stimulated considerable research to determine the vitamin content of different vegetables and also to determine what factors are responsible for variation in vitamin content. The effect of environment on the vitamin content of tomatoes has been reported by Hamner, *et al.* (4), Ellis and Hamner (3), and Murphy (10). Variations in the vitamin content of turnip greens have been studied by Bernstein, *et al.* (1) and by Reder, *et al.* (11). Variation in the vitamin content of carrots, snap beans and lima beans has been reported by Hansen (5), Heinze, *et al.* (6) and Eheart, *et al.* (2). These workers have all come to essentially the same conclusion as that presented by the author in a previous paper (7), that is, the climatic factors associated with different locations or seasons exert a greater influence on the relative vitamin content than variety, soil type, or fertilizer application. A number of workers have shown that the intensity of light to which the particular plant part, fruit or leaf, is subjected to, influences the ascorbic acid content. High light intensity is associated with high ascorbic acid content.

Materials and Methods

During the period from October, 1944, to April, 1945, Georgia or Southern collards and Italian green sprouting broccoli were grown at eight locations in Florida, ranging from Homestead in the extreme south to Quincy in the north. Two crops were grown at Gainesville; the first crop was harvested in January and the second in April. All plants came from the same lot of seed and, with the exception of the April crop at Gainesville and those grown at Homestead and Bradenton, the plants all came from the same seedbed. During the period from October to May, two varieties of carrots, Danvers Half-Long and Imperator, were grown at seven locations, ranging from Homestead in the south to Gainesville in the north. Because of this wide range in latitude, the crops were grown in a number of different climates and soils. The crops were grown with one-half normal, normal and one and one-half normal amounts of fertilizer; the normal being the average amount commonly used for that particular crop, soil type and area. Each treatment was replicated twice at all locations. Broccoli was harvested when it reached commercial maturity by removing the apical bud and a portion of the stem. To obtain comparable samples, the stem, including the bud, was cut to 6 inches in length.

Since it is the vegetative part of the collard plant which is eaten, the entire above-ground portion of the collard plant was harvested. It is difficult to judge by its appearance the stage of maturity or growth of the vegetative collard plant. To obtain samples of collards which would be of comparable maturity at all locations, they were planted and harvested the same time as the broccoli, which has a shorter cycle of development. It seemed that this would give a more uniform sample than harvesting at a certain age since the broccoli would reflect a uniform environmental exposure. Most of the carrots were an inch or more in diameter and none were less than ½ inch in diameter when harvested. No attempt was made to harvest the carrots at any certain age. Two different harvests of the same plots of carrots were made at Gainesville and Homestead.

The samples were brought to Gainesville and stored at 5 degrees C until sampled for analyses, which was usually completed within 36 hours after harvest. The per cent dry weight was determined by drying two 100-gram samples at 75 degrees C in a forced draft oven. A modification of the Morrell method (9) was used for ascorbic acid determinations. The method of Wall and Kelly (12) was used to determine carotene.

RESULTS AND DISCUSSION

Broccoli and Collards:—The broccoli and collards were grown at the same time and have somewhat similar amounts of dry weight, ascorbic acid and carotene (Table I). There was considerable difference in the growth of the crops at different locations as shown by the weight of the 10 heads used in the analysis. The collards and broccoli plants grew much larger at Homestead than at any other location. The amount of fertilizer was a limiting factor for growth at most of the locations, as shown by the increase in average weight of samples with increase in amount of fertilizer applied. The greatest response was from half normal to normal, indicating that the normal amount of fertilizer was usually sufficient. The broccoli grown at Quincy, Hastings and the second planting at Gainesville and the collards grown at

TABLE I—EFFECT OF LOCATION ON SIZE OF PLANT, PER CENT DRY WEIGHT AND ASCORBIC ACID CONTENT OF COLLARDS AND BROCCOLI*

Locations	Weight of Ten Heads (Pounds)		Dry Weight (Per Cent Fresh Weight)		Ascorbic Acid (Mgm Per 100 Grams Fresh Weight)		Carotene (Mg Per 100 Grams Fresh Weight)	
	Broccoli	Collards	Broccoli	Collards	Broccoli	Collards	Broccoli	Collards
Quincy	1.6	4.4	10.6	12.3	80.7	96.5	1.10	4.02
Gainesville (January)	4.3	10.7	10.5	11.7	77.2	74.7	0.81	3.33
Gainesville (April)	2.4	11.4	11.5	13.3	67.6	91.2	1.20	3.81
Hastings	2.1	7.0	11.1	11.0	80.8	76.8	1.01	3.64
Leesburg	2.6	5.7	12.4	15.0	98.5	104.7	1.12	3.87
Sanford	2.3	9.3	9.6	10.0	81.0	73.2	1.17	4.64
Bradenton	4.1	16.4	10.6	12.4	72.0	72.0	0.98	4.04
Belle Glade	2.5	13.0	10.3	11.3	80.7	67.5	0.93	3.28
Homestead	8.6	88.3	9.5	11.2	56.0	52.0	0.68	4.45
Difference necessary for significance: At odds of:								
20 to 1	0.89	5.09	0.4	1.2	5.2	12.7	0.201	0.727
99 to 1	1.23	7.02	0.6	1.6	7.2	17.5	0.277	1.002

*Each value is an average of six determinations, two from each of the three fertilizer levels.

TABLE II—EFFECT OF FERTILIZER LEVEL ON THE SIZE OF THE PLANT, THE PER CENT DRY WEIGHT AND ASCORBIC ACID AND CAROTENE CONTENT OF BROCCOLI AND COLLARDS GROWN AT EIGHT LOCATIONS IN FLORIDA*

Crop	Rate of Fertilization			Least Difference Necessary for Significance At Odds of	
	½ Normal	1 Normal	1½ Normal	20 to 1	99 to 1
	Dry Weight (Per Cent Fresh Weight)				
Broccoli	10.7	10.7	10.5	0.3	0.4
Collards	12.6	11.8	11.7	0.7	0.9
	Ascorbic Acid (Milligrams Per 100 Grams Fresh Weight)				
Broccoli	81.7	78.2	78.1	3.0	4.1
Collards	81.7	78.3	76.2	7.3	10.1
	Carotene (Milligrams Per 100 Grams Fresh Weight)				
Broccoli	0.93	1.03	1.04	0.117	0.161
Collards	3.69	3.80	4.20	0.420	0.578
	Weight of Ten Heads				
Broccoli	2.7	3.7	3.8	0.51	0.70
Collards	16.1	19.4	20.2	2.94	4.05

*Each value is an average of 16 determinations 2 from each location.

Belle Glade and Hastings did not respond to increase in fertilizer. Dry weight, ascorbic acid and carotene vary considerably from location to location. There is, however, little relationship between the size of the plant and per cent dry weight, ascorbic acid or carotene content. While the amount of fertilizer did affect the size of the plants (Table II) it had little effect on any of the constituents measured. The increase in carotene content of collards with an increase in amount of fertilizer was significant, although this difference was very small in comparison to the differences associated with location.

TABLE III—THE EFFECT OF LOCATION ON SIZE OF ROOTS, PER CENT DRY WEIGHT, AND ASCORBIC ACID AND CAROTENE CONTENT OF TWO VARIETIES OF CARROTS

Location	Number of Days From Seed to Harvest	Weight of Ten Roots (Grams)		Dry Weight (Per Cent Fresh Weight)		Ascorbic Acid (Mgs Per 100 Grams Fresh Weight)		Carotene (Mgs Per 100 Grams Fresh Weight)	
		Danvers	Imperator	Danvers	Imperator	Danvers	Imperator	Danvers	Imperator
Gainesville	131	571	439	10.6	10.5	14.8	13.4	4.98	5.35
Gainesville (second harvest)	186	1,715	1,391	12.3	12.4	—	—	9.73	10.56
Sanford	122	768	632	11.9	12.0	17.8†	13.3†	6.55	6.92
Homestead	88	437	476	10.9	12.0	9.7†	8.8†	4.56	4.60
Homestead (second harvest)	97	639	651	11.3	12.6	12.0	12.0	4.74	5.81
Belle Glade	138	967	845	10.5	11.6	15.5†	12.4*	6.03	7.22
Leesburg	141	413	503	11.8	12.4	13.8†	12.0*	8.28	8.05
Hastings	119	398	263	18.1	18.8	14.2†	13.3*	11.60	10.91
Bradenton	111	1,655	1,352	13.0	14.0	11.5†	8.0*	8.94	8.84
Least difference necessary for significance. At odds of:									
20 to 1	—	232	50	0.76	0.80	—	—	1.367	1.448
	—	320	69	1.05	1.11	—	—	1.884	1.995

*Each value is an average of six determinations; two from each of the three fertilizer levels.
†Based on samples from fertilizer level 1 only.

TABLE IV—THE EFFECT OF FERTILIZER LEVEL ON THE SIZE OF THE ROOT, THE PER CENT DRY WEIGHT AND ASCORBIC ACID AND CAROTENE CONTENT OF IMPERATOR AND DANVERS HALF LONG CARROTS*

Variety	Rate of Fertilization			Least Difference Necessary for Significance At Odds of	
	½ Normal	1 Normal	1½ Normal	20 to 1	99 to 1
Dry Weight (Per Cent Fresh Weight)					
Danvers	12.2	12.2	12.4	0.44	0.61
Imperator	12.9	12.7	13.1	0.46	0.64
Ascorbic Acid (Milligrams Per 100 Grams Fresh Weight)					
Danvers	16.4†	13.6	13.8†	——	——
Imperator	12.9†	13.8	12.9†	——	——
Carotene (Milligrams Per 100 Grams Fresh Weight)					
Danvers	7.06	6.90	7.59	0.789	1.087
Imperator	7.40	7.68	7.67	0.836	1.152
Weight of Ten Roots (Grams)					
Danvers	863	889	779	95	130
Imperator	737	728	718	29	40

*Each value is an average of 18 determinations, two from each harvest at each location.
†Based on two samples from Gainesville.

TABLE V—THE PER CENT DRY WEIGHT AND ASCORBIC ACID, CAROTENE CONTENT OF THE APICAL SHOOTS AND LATERAL SHOOTS OF BROCCOLI*

Location	Date Harvested		Dry Weight Per Cent Fresh Weight		Ascorbic Acid (Mgs Per 100 Grams)		Carotene (Mgs Per 100 Gms)	
	Apical Shoot	Lateral Shoots	Apical Shoot	Lateral Shoot	Apical Shoot	Lateral Shoots	Apical Shoot	Lateral Shoots
Bradenton	Dec 28, 1944	Jan 22, 1945	10.6	11.6	72	64	0.98	0.66
Sanford	Jan 8, 1945	Jan 23, 1945	9.6	11.5	81	84	1.17	1.13
Hastings	Jan 4, 1945	Feb 16, 1945	11.1	12.9	81	101	1.01	1.78
Gainesville (winter)	Jan 22, 1945	Feb 13, 1945	10.5	11.2	77	84	0.81	1.65

*Each value is an average of six determinations, two from each of the three fertilizer levels.

Samples of the secondary or lateral shoots of broccoli were obtained from plots at Bradenton, Hastings, Sanford and Gainesville. The analysis of these samples is compared with that of the apical shoots in Table V. There was considerable difference between the apical shoots and the lateral shoots obtained from all four locations. The dry weight is the only constituent which is uniformly different in the two sets of samples. There is 1 to 1.5 per cent higher dry weight in the lateral shoots than in the apical shoots.

Carrots:—The average weight of the 10 roots used in the analysis shows considerable variation in growth from one location to another. Part of this growth is due to age and part due to different environments. Statistically there is no significant effect of fertilizer on the growth of the carrots. There was some indication, however, that the higher fertilizer levels retarded the growth, this was more pronounced at Bradenton and Gainesville. The Danvers carrots were usually larger than the Imperator carrots but they were much less uniform in their growth as indicated by the larger differences in weight necessary for significance, for the Danvers. Since the ascorbic acid content is rather low in carrots, only the samples from the normal fertilizer plots, except those fom Gainesville, were analyzed for ascorbic acid. Hansen (5) and Janes (8) have both shown that the carotene content of carrots increases with increase in age of carrots. Since the carrots in these studies were harvested at various ages, part of the difference in carotene content from location to location can be attributed to this difference in age. However, this difference in age only accounts for part of the difference between locations. The carrots grown at Belle Glade were 138 days old when harvested and had a carotene content of 6 to 7 milligrams per 100 grams, while the carrots grown at Hastings were only 111 days old at harvest and had a carotene content of 11 to 11.5 milligrams per 100 grams.

It is obvious that the greatest variation in ascorbic acid and carotene content of vegetables is associated with different crops. When any one crop is considered, however, variations in climatic conditions are the most important factor in determining the concentration of these vitamins. The variation in vitamin content from location to location was quite large for the three crops reported. The soil varied from location to location and could possibly have exerted an influence on the vitamin content. The two crops of broccoli and collards grown at Gainesville were on the same soil type but still had considerable difference in their vitamin content. There was a marked difference between the two samples of broccoli from the same plants harvested at different times. Some of this difference might have been due to change in physiology of the plane due to aging but, since the differences in vitamin content were not uniform, it would indicate that the change in environment was responsible for the differences. The environment in this case would have to be climatic, since the soil was the same. The small difference as a result of fertilizer treatments would also indicate that the climatic factors and not the soil influenced the vitamin content. As was stated in the introduction, a number of other workers have arrived at essentially this same conclusion.

Another interesting point is the relationship of one constituent to another. There is a positive correlation between the per cent dry weight and the ascorbic acid content in both collards and broccoli. The correlation coefficients are +.73 for broccoli and +.72 for collards. Bernstein, *et al.* (1) reported that high ascorbic acid content of turnip greens was associated with low carotene content and vice-versa. In the studies reported here, the correlation coefficient between carotene and ascorbic acid was +.48 for broccoli and —.15 for collards. This correlation is significant for broccoli and not for collards. It is evident that both the ascorbic acid and carotene contents of crops are influenced by climatic factors. Bernstein, *et al.* (1) concluded that a factor that brings about high ascorbic acid would result in low carotene. This was undoubtedly the case with the turnip greens used in their studies. However, since the two crops studied here responded differently from each other and differently from the turnip greens, it would seem that, while both carotene and ascorbic acid are affected by climatic factors, there is little relation between the two constituents. There are undoubtedly several physiological factors within the plant, as well as several climatic factors which determine the carotene and ascorbic acid content. The interaction of these factors permits considerable variation in the relative concentration of these two constituents.

Summary

Collards, broccoli, and carrots which were grown at three fertilizer levels at eight locations in Florida were analyzed for dry weight, ascorbic acid and carotene content. There was a large variation in the percentage of these constituents from location to location and from season to season. There was little or no effect of fertilizer level on the percentage of the constituents in the plants. High ascorbic acid content was correlated with high dry weight.

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Effect of Sunlight Exposure on the Quality Constituents of Tomato Fruits

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It has been shown (3) that exposure of tomato fruits to sunlight is an important factor affecting the ascorbic acid content. The object of this study was to determine if other quality constituents as well as ascorbic acid vary with sunlight exposure of the fruits.

METHODS

Each sample consisted of 12 or more fruits selected from field grown plants for uniformity of size, ripeness and light exposure. Where the method of sampling is not otherwise stated, equal sectors from opposite sides of each fruit were taken. For ascorbic acid determinations the samples were blended in a Waring blendor with one ml of .5 per cent oxalic acid per 1 gram of tomato for 2 minutes. The juice was then filtered and titrated with 2,6–dichlorobenzenoneindophenol standardized with ascorbic acid.

A glass electrode was used for pH readings. Sugars were determined by a modification of the method of Willaman and Davidson (5) and expressed as dextrose. Total solids were determined by drying a 20 gram blended sample to constant weight at 80 degrees C in a Brabender ventilated oven. The method used for carotenoids was a modification of one previously reported by the writer (3).

RESULTS

Ripe samples of shaded and unshaded fruits of the Garden State variety were used to determine the effect of sunlight exposure on the sugar, total solids and carotenoid as well as the ascorbic acid content of tomato fruits. Analyses were made September 7 and September 22, early and late in the harvesting season, respectively.

The data, Table I, show in the case of both early and late analyses a striking increase in ascorbic acid for the unshaded over the shaded fruits. Sugars follow the same trend as ascorbic acid but with only a

TABLE I—ANALYSES OF EXPOSED AND SHADED TOMATO FRUITS OF THE GARDEN STATE VARIETY

Treatment	pH	Mgs Per 100 Grams		Grams Per 100 Grams		
		Ascorbic Acid	Carotenoids	Total Solids	Reducing Sugars	Total Sugars
September 7, 1945						
Exposed	4.73	40.2	6.14	5.95	3.45	3.61
Shaded	4.48	25.7	8.06	5.65	3.00	3.19
September 22, 1945						
Exposed	4.75	31.5	8.30	5.43	2.72	3.10
Shaded	4.55	22.4	7.20	5.42	2.65	2.97

slight difference in the case of the September 22 analyses. At this time the plants had lost much of their foliage so it was impossible to know how long the exposed fruits had been unshaded.

The shaded fruits in the early test were higher in total pigments than the unshaded, even though they were less ripe physiologically as indicated by a lower pH. Early in the season temperatures of exposed fruits are often too high for lycopene formation (4).

The effect of the sunlight exposure of the fruit on quality constituents is further demonstrated by analyses of upper and lower sectors of the fruit. Unshaded fruits with longitudinal axes parallel to the ground were marked as to position and harvested. They were cut into one-quarter sectors. The uppers (toward the light) and lowers (away from the light) were analyzed separately. Tests were made September 5, 1945, with Illinois T19 and September 28, 1943, with Early Baltimore. The upper sectors in both tests as shown by the data, Table II, were higher in ascorbic acid, total solids, and sugars than the lower ones. The upper sectors of Illinois T19 analyzed early in the harvesting season were lower in total carotenoids than the lower ones. This was not the case with Early Baltimore analyzed late in the season when the temperatures of exposed fruits were less likely to be too high for lycopene development.

TABLE II—Analyses of Upper and Lower Quarter Sectors of Unshaded Fruits

Portion Analyzed	Mgs Per 100 Grams			Grams Per 100 Grams		
	pH	Ascorbic Acid	Carotenoids	Total Solids	Reducing Sugars	Total Sugars
			Illinois T19, September 5, 1945			
Upper Sector	4.82	47.6	6.14	5.15	2.68	2.84
Lower Sector	4.78	32.5	8.78	4.30	2.06	2.25
			Early Baltimore, September 28, 1943			
Upper Sector	4.22	40.5	10.0	5.30	2.83	3.35
Lower Sector	4.33	28.1	10.0	5.05	2.67	2.97

If the differences in ascorbic acid and sugar content between the upper and lower sectors of a fruit are due to sunlight exposure, then greater differences should be expected between the upper and lower sides of exposed than those of shaded fruits. The upper and lower one-quarter sectors of shaded and unshaded fruits of the Garden State variety were analyzed as in the previous experiment. The data, Table III, show that there are striking differences in ascorbic acid and sugars in favor of the upper over lower sectors of the unshaded fruits, but in the case of the shaded fruits the differences are negligible.

In an effort to determine the composition of different parts of the tomato fruit it was found that with some samples the outer pericarp was highest in ascorbic acid. In others the locular jelly was highest as reported by Maclinn and Fellers (1). In order to determine if this discrepancy might be due in part to the sunlight exposure of the fruits, shaded and unshaded fruits of Campbell's No. 178 were divided

TABLE III—ANALYSES OF UPPER AND LOWER QUARTER SECTORS OF SHADED AND UNSHADED FRUITS GARDEN STATE VARIETY, SEPTEMBER 26, 1945

Portion Analyzed	Mgs Per 100 Grams			Grams Per 100 Grams		
	pH	Ascorbic Acid	Carotenoids	Total Solids	Reducing Sugars	Total Sugars
			Unshaded			
Upper Sector	4.40	28.1	7.44	5.24	2.93	3.10
Lower Sector	4.42	22.6	7.80	4.90	2.72	2.80
			Shaded			
Upper Sector	4.57	20.2	8.30	4.93	2.10	2.20
Lower Sector	4.53	19.7	7.88	4.73	2.05	2.17

into three parts: (a) outer pericarp, (b) locular jelly and (c) inner pericarp and placenta. These were weighed and analyzed separately.

The data, Table IV, show in the case of the unshaded fruits that the outer pericarp was highest in sugars as well as ascorbic acid and the placental tissue lowest. There was a decrease of these constituents toward the center of the fruits. With the shaded fruits the locular jelly was highest in ascorbic acid but lowest in sugars. The latter difference, however, is small and perhaps not significant. These data may partially explain the relatively high ascorbic acid content of the locular jelly reported by Maclinn and Fellers. They used the Comet variety grown in the greenhouse where the fruits normally receive a low light exposure.

TABLE IV—ANALYSES OF SHADED AND UNSHADED TOMATO FRUITS DIVIDED INTO OUTER PERICARP, INNER PERICARP AND PLACENTA, AND LOCULAR JELLY OF CAMPBELL'S NO 178 VARIETY

Part of Fruit Analyzed	Mgs Per 100 Grams			Grams Per 100 Grams		
	pH	Per Cent	Ascorbic Acid	Total Solids	Reducing Sugars	Total Sugars
			Unshaded Trees			
Outer Pericarp	4.52	41.30	35.6	5.50	3.19	3.50
Loculary Jelly	4.52	21.53	32.2	5.10	2.78	3.05
Inner Pericarp and Placenta	4.47	37.16	21.1	5.20	2.60	2.80
Fruit Average	4.50	----	29.5	5.30	2.88	3.14
			Shaded Fruits			
Outer Pericarp	4.50	42.09	23.0	4.80	2.21	2.46
Loculary Jelly	4.67	23.08	26.4	4.50	2.12	2.33
Inner Pericarp and Placenta	4.49	34.83	17.1	4.05	2.25	2.40
Fruit Average	4.54	——	21.7	4.47	2.20	2.41

SUMMARY AND CONCLUSIONS

The data presented show unshaded fruits to be higher in ascorbic acid, total solids and sugars than the shaded ones. Fruits are also shown to vary in these constituents from one side to the other depending upon sunlight exposure. The extent to which fruits are shaded is therefore an important factor in sampling for quality studies. The data indicates that a tomato fruit functions as a photosynthetic organ even though it has no stomates or lenticels. The exposed fruits, although high in quality constituents, may be low in total carotenoids, especially when high temperatures prevail.

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Effect of Plant-Growth Regulators on the Set of Fruit from Hand-Pollinated Flowers in *Cucumis melo* L.[1]

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IN *Cucumis melo* L. the flower structure and stickiness of the pollen are such that a considerable amount of cross pollination occurs under field conditions. According to Rosa (4) from 5 to 15 per cent of the seed of the hermaphrodite-flowered varieties may be cross-fertilized where different varieties are grown in adjoining rows. As a rule the intervention of insects is necessary for successful pollination and fertilization of the flowers of this species. For this reason in breeding programs designed to improve the adaptability and disease-resistant qualities of muskmelons and cantaloups serious consideration must be given to techniques of controlled pollination. Obviously, artificial pollination offers one method by which it is possible to establish and maintain desirable combinations of genes.

Our records covering a period of about four years indicate that approximately one-third of hand-pollinated flowers set and subsequently mature fruit. These data, summarized in Table I, are based on a substantial number of flowers, and are therefore likely to be a reliable index of what one may expect from hand pollination in two very different environments. Brawley is typical of the arid, hot, inland valleys of the Southwest, and Torrey Pines is representative of the cooler coastal belt of California from Los Angeles southward.

The average set obtained at Torrey Pines is about 15 percentage points higher than that obtained at Brawley. This difference probably represents an actual one reflecting the somewhat less rigorous climatic conditions found at Torrey Pines.

TABLE I—PERCENTAGE SET OF HAND-POLLINATED FLOWERS IN *Cucumis melo*

Location	Year	No. Flowers Pollinated	Per Cent Set
Torrey Pines	1942	781	37.51
Torrey Pines	1943	171	36.25
Torrey Pines	1944	227	40.09
Torrey Pines	1945	119	53.02
Brawley	1943	938	27.29
Brawley	1944	1,171	28.79
Brawley	1945	1,177	24.04
Brawley	1946	1,427	16.75

The figures from which these yearly percentages were computed show a remarkable range, varying from only 6.88 per cent on certain days to as much as 65 per cent at other times during the season. We have no satisfactory explanation for these erratic results.

It is evident that any device or technique that would increase the percentage of set from hand-pollinated flowers would be of immense practical value in reducing the time, labor, and effort required to produce the minimum number of hand-pollinated fruits requisite in a well-rounded breeding program.

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The development of the flowers in relation to the environmental variables, temperature and humidity, is fairly well known. Seaton and Kremer (5) have shown that the minimum temperature for anthesis of the flowers and dehiscence of the pollen sacs is 65 degrees F, the optimum for these processes being 70 to 75 degrees. Other meterological factors were found to be of little consequence. Flowers opened and released their pollen equally as well during periods of low humidity as during rainy weather.

There are no recorded cases of self-sterility or cross-sterility among the numerous varieties of this species, and our experience over a period of 10 years suggests that self- or cross-sterility rarely if ever occurs. Therefore, it appears to be unlikely that uncongenial fertility relationships are responsible for the relatively poor set obtained when flowers of this species are artificially pollinated. In general, pollen of all varieties and strains is abundant, and averages about 90 to 95 per cent viable as judged by acetocarmine tests.

The next possibility to be examined was that some growth-regulating substance or plant-hormone deficiency at the time of pollination and fertilization might be the cause of frequent failure of development after artificial pollination. If this suggestion has merit a suitable substance applied at the proper time and in correct concentration might prevent the abscission of the young fruit. There is some experimental evidence that indirectly supports this idea. Wong (6) was able to produce parthenocarpic watermelons by the application of naphthaleneacetic acid to the stigmas of the young pistil. He was also successful in producing parthenocarpic cucumbers by use of the same chemical. Gustafson (2) has produced parthenocarpic fruit of *Cucurbita maxima* and *C. moschata* by means of chemical treatment. On the other hand, efforts to induce seedless fruiting of *C. pepo* have been unsuccessful, for the most part.

Our problem, although similar in some respects to the above-mentioned work in the production of parthenocarpic or seedless fruit, has an entirely different objective. To assure success in pollination it is necessary for the material to function only in assisting the young ovary in its development, and in preventing its separation from the plant. A parthenocarpic or seedless fruit would defeat the purpose of the treatment. Some preliminary results (Burrell and Whitaker, 1) were sufficiently encouraging to justify continuation of the work on a larger scale, using several growth-promoting substances and applying them in different concentrations.

MATERIALS AND METHODS

In our preliminary experiments, in addition to the four ordinary growth-promoting substances, indoleacetic acid, indolepropionic acid, indolebutyric acid, and α-naphthalene acetamide, an ether extract of cantaloup pollen, non-viable pollen in lanolin, and lanolin alone were used. Later, as they became available, α-naphthaleneacetic acid, β-

naphthoxyacetic acid, and some of the substituted phenoxy compounds were tried.

Some exploratory work indicated that the most effective means of applying these materials was to use lanolin in the paste form as a carrier. A few tests applying materials in liquid form by means of an atomizer were not successful and this method of application was abandoned. Preliminary tests provided evidence that for the majority of the materials used concentrations of 10 to 25 mg/gram of lanolin were sufficiently near optimum to give satisfactory results.

During the early phases of the work in order to facilitate statistical analysis the pollinations were made in pairs; one, two, three, or four treated flowers were matched with an equal number of untreated flowers from an adjacent vine. This method proved to be rather cumbersome and was relinquished in favor of a system by which the number of treated and untreated flowers were approximately the same, but were not necessarily matched in pairs. All flowers on an individual vine were either treated or left untreated.

Considerable importance is attached to the method of application. At first a small quantity of the material was placed on the stigma after pollination. However, experience showed that the most effective method of application was to detach the corolla where it joins the ovary, and apply the material to the torn surface. Approximately 7 micrograms of the test compound were applied per flower. In this operation care should be taken not to damage the young ovary. Very often after treatment the developing ovary had a characteristically enlarged or contorted appearance, probably the result of more rapid growth and expansion of the cells directly in contact with the material. As the young fruit continued to develop, it became normal in appearance, and externally at least could not be distinguished from an untreated fruit.

EXPERIMENTAL RESULTS

Our preliminary results with ether extract of pollen, pollen in lanolin, indoleacetic acid, indolebutyric acid, and naphthalene acetamide did not yield a significant increase in the percentage of set; and, except for indoleacetic acid, these materials were discarded in further experimentation. In the preliminary work indolepropionic acid proved to be the most promising material, and thereafter our efforts were confined to tests with this substance either alone or in combination with indoleacetic acid, and those with α-naphthaleneacetic acid, β-naphthoxyacetic acid, and some of the substituted phenoxy compounds (see Table II).

Indolepropionic acid was given a very thorough trial over a period of two years at three concentrations (10, 25, and 50 mg/gram), and except for the highest concentration (50 mg/gram), was tested at each location. The results (see Table II) do not indicate a definite trend, and when the chi-square test is applied none of the differences proved to be significant.

The next step was to try the most promising of these chemicals in combination, on the assumption that they might supplement each other in jointly producing effective results. A group of experiments using a

TABLE II—PERCENTAGE SET OBTAINED FROM VARIOUS EXPERIMENTAL TREATMENTS

Location	Year	Treatment	Conc. Mg/G	No. Flowers Pollinated		Set (Per Cent)	
				Treated	Check	Treated	Check
Brawley	1943	Indolepropionic Acid	10	751	729	25.17	20.44
Brawley	1943	Indolepropionic Acid	50	232	209	40.09	51.20
Torrey Pines	1943	Indolepropionic Acid	25	188	171	44.15	36.26
Brawley	1944	Indolepropionic Acid	10	1,090	980	24.50	27.35
Brawley	1944	Indolepropionic Acid	25	171	163	32.75	36.81
Torrey Pines	1944	Indolepropionic Acid	10	22	25	36.36	32.00
Torrey Pines	1944	Indolepropionic Acid + Indoleacetic Acid	5 + 5	213	202	50.23	41.09
Brawley	1945	α-napthaleneacetic Acid	10	220	275	3.18	10.55
Brawley	1945	Indolepropionic Acid + Indoleacetic Acid	5 + 5	458	602	17.03	24.58
Brawley	1945	β-naphthoxyacetic Acid	10	206	236	36.89	36.86
Torrey Pines	1945	β-napthoxyacetic Acid	10	155	149	61.29	53.02
Brawley	1946	2, 4, 5-trichlorophenoxyacetic Acid	25	133	147	1.50	9.52
Brawley	1946	α-(2-Chlorophenoxy)-Propionic Acid	25	401	349	1.75	6.88
Brawley	1946	4-Chlorophenoxyacetic Acid	10	199	230	35.18	12.61*
Brawley	1946	2-Chlorophenoxyacetic Acid	10	262	283	28.24	28.62
Brawley	1946	2, 4, 6-Trichlorophenoxyacetic Acid	10	170	188	12.94	21.28
Brawley	1946	2, 4-Dichlorophenoxyacetic Acid	10	145	156	6.90	19.87

*Highly significant difference.

combination of 5 milligrams indoleacetic acid plus 5 milligrams indolepropionic acid per gram of lanolin produced some encouraging results at Torrey Pines, but when tested on a more extensive scale the following spring at Brawley the trend appeared to be in the opposite direction. However, the differences at either location were not significant.

β-Naphthoxyacetic acid, 2, 4, 5-trichlorophenoxyacetic acid, α-(2-chlorophenoxy)-propionic acid, 2-chlorophenoxyacetic acid; 2, 4, 6–trichlorophenoxyacetic acid and 2, 4–dichlorophenoxyacetic acid were not effective in improving the set of hand-pollinated melons. At least three of these substances were actually toxic in the concentrations used, for example, 2, 4, 5–trichlorophenoxyacetic acid, α-(2–chlorophenoxy)-propionic acid, and 2, 4-dichlorophenoxyacetic acid.

4-Chlorophenoxyacetic acid proved to be the most effective substance tested for improving the set of hand-pollinated melons. In two experiments involving 429 (199 treated) flowers an increase of about 22 in percentage points was recorded over untreated flowers (see Table II). The chi-square test indicates that the difference is highly significant, exceeding the one per cent level.

The above results with 4–chlorophenoxyacetic acid were calculated from the pooled data of two experiments at Brawley, each one of which yielded a significant difference as shown below.

Experiment No.	Date	No Flowers Pollinated		Set (Per Cent)	
		Treated	Check	Treated	Check
1	May 2, 1946	147	171	26.53	7.60*
2	May 17, 1946	52	59	59.62	27.12*

*Highly significant difference.

During the current season at Torrey Pines (summer, 1946), four experiments with 127 flowers gave an increase in percentage set of about 23 for the treated flowers over untreated ones as the result of using 4–chlorophenoxyacetic acid. The chi-square test when applied to these data indicates that the difference is highly significant.

DISCUSSION

The idea of using growth-regulating substances to supplement hand pollination, as suggested by Burrell and Whitaker (1), offers attractive possibilities, as was pointed out by Gustafson (3). It is conceivable that future experimentation may show that certain of these growth-regulating chemicals can be an effective tool in the hands of the plant breeder, particularly in those species in which the yield of seed from hand pollination has a tendency to be poor.

Casual observations make it seem unlikely that poor set of fruit following artificial pollination in *Cucumis melo* can be attributed entirely to growth-substance or vitamin deficiency. It is not improbable that small differences in temperature and humidity, combined with inequalities of plant vigor, age of plant, time of pollination with reference to the flowering cycle, and other conditions connected with the physiology of the individual plant, have minor, but definite influences upon the results of artificial pollination. Our present techniques are not refined to the point where we can separate out and measure these effects.

That our results with indoleacetic acid were not in agreement with the preliminary results of previous workers (1) can probably be attributed to the fact that flowers treated with growth substances, particularly indoleacetic acid and indolepropionic acid, tend to remain green and in apparently viable condition much longer than comparable untreated flowers. Thus the final determination of whether a particular flower will develop into a mature fruit cannot be judged as a rule until two or three weeks after pollination. Futhermore, because of the wide variation in the percentages of flowers that set from day to day, it is believed that a large number of flowers must be used (at least 100) over a period of several weeks before one can evaluate the results of a treatment.

The results with 4–chlorophenoxyacetic acid appear to be very promising and the use of this substance should be extremely helpful in a breeding program where a considerable number of hand-pollinated fruits are required. Other substituted phenoxy compounds should be tested in order to evaluate their usefulness for this purpose. It is not unlikely that several of them will prove to be useful. However, as Zimmerman (7) points out, comparative activity of these substances cannot be predicted from the appearance of the structural formulas. The activity of each substance must be determined by actual biological tests.

SUMMARY

Records over a period of four years in two very different environments indicate that about one-third of artificially pollinated flowers of

Cucumis melo set fruit. Attempts to increase the percentage of set through the supplemental use of indoleacetic acid, indolepropionic acid, indolebutyric acid, naphthalene acetamide, an ether extract of cantaloup pollen, non-viable pollen in lanolin, α-naphthaleneacetic acid, β-naphthoxyacetic acid, and certain of the substituted phenoxy compounds were uniformly unsuccessful.

A significant increase in the set of fruit was obtained by use of one of the substituted phenoxy compounds, 4–chlorophenoxyacetic acid. Experiments with 398 treated flowers indicate that an increase in set of about 22 in percentage points can be anticipated by treating the flowers with this substance at the time of pollination. This would mean some 22 additional fruits from every 100 hand pollinations.

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Thinning Hawkesbury Watermelons to Increase Fruit Size[1]

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THE Hawkesbury wilt-resistant watermelon, originated in Australia and introduced into Indiana by the Purdue University Agricultural Experiment Station in 1938 and 1939, has become by far the leading variety in the State. It is highly prolific, but, because of its tendency to set so many fruits, there seemed to be a possibility of getting an increase in average fruit size by thinning. In spite of commonly expressed opinion that small watermelons should be desirable for small families and for fitting into electric refrigerator space, carlot and truck-load buyers still strongly prefer the large sizes. Ordinarily there is a discount for small size, and when there is an abundance of larger watermelons, smaller ones may not sell at all.

Thinning of watermelons is not a commercial practice in Indiana. With some varieties it is scarcely feasible because of the difficulty of finding the small sets. Young Hawkesbury fruits, having a light-colored rind, are, however, easier to locate.

EXPERIMENTAL TREATMENTS AND CONDITIONS

The four different treatments compared in this experiment were defined as follows:

A. Fruits thinned and kept thinned to one per plant. The first unscarred, well-shaped fruit was allowed to develop. All others were removed once a week. Fruits with small rotted spots or other defects were taken off even though they were the only ones on the plant.

B. Fruits thinned and kept thinned to two per plant. The first two unscarred, well-shaped fruits were allowed to develop. All others were removed once a week. Fruits with any sort of defect were taken off even though by so doing no fruits were left on the vine.

C. Fruits thinned only to the extent of removing defective specimens. Plants were examined once a week and fruits in any way defective were removed.

D. Fruits not thinned.

In order to maintain the vines in conformity with these specifications, single plant plots had to be used. Plants were spaced 8 x 12 feet and kept carefully restricted to their alloted areas by turning vines back on themselves at frequent intervals. There were 21 sets of replicates at the beginning, but the loss of 7 plants left only 15 complete blocks. For the sake of simplicity in the presentation of the results and because of the fact that use of the results from the incomplete blocks does not make any practical change in the relation of the means or in the significance of the differences, data from only the 15 complete replicates are here considered.

The melons were started in 5-inch veneer bands under glass, without artificial heat. They were moved to a field at the Southwestern Indiana Horticultural Experiment Farm, near Owensville, on May 28, 1945. This was much later than is normal, but setting was delayed because of unusually cold and wet weather. The soil was Princeton fine sand; the fertilizer, 125 pounds of ammonium nitrate per acre, 500 pounds of 20 per cent superphosphate, 167 pounds of 60 per cent muriate of potash, and 25 pounds of borax, all plowed down with a heavy rye cover crop. To control leaf diseases, spraying with 3–3–100 Bordeaux was practiced on August 8 and August 16.

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[1] Journal Article No. 251 of the Purdue University Agr. Exp Sta.

On the whole, the season was much too cool and rainy for watermelons, but even with these unfavorable conditions, production and quality were fairly good. Maturity, however, was delayed a week or more beyond the normal date.

Harvesting began on August 18 and continued until September 19 No unmarketable fruit or fruit too ill-shaped for the U. S. No. 1 grade was harvested; also none weighing less than 15 pounds and perhaps not all within the 15- to 17-pound range. Harvest records were taken by Mr. Charles E. Sims, farm superintendent.

RESULTS

A summary of some of the results is presented in Table I.

TABLE I—YIELD AND FRUIT SIZE OF WATERMELONS AS AFFECTED BY THINNING OF FRUITS

	Treatments*				Difference Necessary for Significance at 5 Per Cent Point
	A Kept Thinned to One Fruit Per Plant	B Kept Thinned to Two Fruits Per Plant	C Defective Fruits Removed	D No Thinning	
Data for Harvests Preceding September 1					
Yield of all No 1 fruit (tons per acre)	5.1	4.5	6.0	4.7	N.S.**
Yield of No. 1 fruit weighing 20 pounds or more (tons per acre)	3.9	3.7	5.3	4.1	N.S.
Yield of No. 1 fruit weighing 23 pounds or more (tons per acre)	3.9	3.4	3.2	2.5	N.S
Yield of No. 1 fruit weighing 26 pounds or more (tons per acre) .	3.9	2.6	2.1	1.8	N.S.
Data for Whole Season					
Yield of all No. 1 fruit (tons per acre)	6.6	9.5	15.7	18.9	5.8
Yield of No. 1 fruit weighing 20 pounds or more (tons per acre)	5.5	8.4	14.4	16.2	5.8
Yield of No. 1 fruit weighing 23 pounds or more (tons per acre)	5.5	7.2	9.0	9.9	N.S.
Yield of No 1 fruit weighing 26 pounds or more (tons per acre)...	4.4	6.0	5.4	5.6	N.S.
Average size of all No. 1 fruits (Pounds) .	25.7	24.9	23.0	22.9	N.S.

*Refer to text for more complete definition of different treatments.
**N.S. means no significant differences.

CONCLUSION

Even when the normal price differentials in favor of the larger sizes and in favor of melons harvested before September 1 are taken into account, the experiment tends to indicate that it was not profiable to do any thinning whatsoever with the Hawkesbury variety.

The Improvement of Native White Beans *(Phaseolus vulgaris)* by Selection[1]

By P. González Ríos and Arturo Riollano, *Agricultural Experiment Station, Río Piedras, P. R.*

Field beans are one of the major food crops of Puerto Rico. During the prewar period yearly importations amounted to a little over the 100,000,000-pound mark with a cash value of around $3,000,000. This represented about two-thirds of the total consumption of the Island. The balance, one-third, was produced and consumed locally. The beans produced locally are preferred to the imported by the Puertoricans who consider them to be of superior quality.

Native white beans have been grown in Puerto Rico for the last three or four centuries. The origin of these beans is rather obscure The fact that they are called "native" shows that they have been many years under cultivation in the Island. During the course of time several new strains and varieties were introduced and so it seems there were possibilities of considerable mixing and crossing of the material available.

In comparison with the average yield of about 700 pounds of beans per acre reported for the United States by Hardenburg (1), our yield per acre is very low. In a recent survey made in Puerto Rico by the extension agents of eighteen districts it was found that the average yield per acre was 472 pounds for the white variety and 321 pounds for the red variety.

During the year of 1934 the Agricultural Coordinating Committee of the University of Puerto Rico, appointed a sub-committee presided by Professor Mortimer F Barrus, Director of the Extension Service, to study the production of bean in Puerto Rico. Among other recommendation, the sub-committee reported: "The varieties now being grown on the Island are largely a small white bean and a small reddish bean both without any other identifying name".

"No selection or breeding work with these beans has been made. It is believed, on the basis of work done elsewhere, that an improvement in yield here could be obtained if such work were conducted."

With these points in view a project for the improvement of the native white and native red beans was prepared and started on July 1, 1936. Since the beginning the work was mainly concentrated upon the improvement of the native white bean. However, following similar lines the phase of the native red bean improvement was begun at a later date and this work is now well advanced, its completion being expected within the next two years.

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[1] This project was financed in part from Bankhead-Jones funds alloted by the Agricultural Research Administration from the Office of Experiment Stations. A considerable proportion of the early work was done by Messrs. Arturo Roque and José Adsuar, who started this project Work was then continued for a while by Dr. G. E. Lebedeff and upon his resignation, it was continued and completed by the authors

BEAN GROWING IN PUERTO RICO

The largest acreages in beans are found in the municipalities of Isabela, Utuado, San Sebastián, Orocovis, Cayey and Morovis. Beans are grown almost in every region of the Island except in the extreme border of the southern coast. The bean fields are small, ranging from less than an acre to two or three acres at most and it is seldom that ten or more acres are planted in a single field. In the tobacco districts of the interior towns beans are planted in furrows after the tobacco has been harvested. On many farms, corn and beans are interplanted in the same field as a mixed crop and at any time of the year.

Beans are also planted on areas of very shallow soil that are not suitable to other crops and although not well adapted to beans, produce higher returns than when planted to other crops. Very often bean crops on shallow soils are affected by drought.

White beans are grown more extensively than red beans, although the latter mature about two weeks earlier. In addition, white beans are heavier yielders and seem to be more vigorous and more resistant to diseases than red beans.

In the coffee regions, the white bean variety is more commonly planted in the spring. Also it is planted during the winter months, when the danger of floods is over, on the alluvial narrow plains along the banks of rivers where excellent crops are harvested. In the lowlands near the coast, beans are planted in the winter months when the heavy rains are over.

When beans are planted late in the spring or in the summer they are usually a complete failure or yields are very low. Late spring plantings sometimes may do well at high altitudes in the interior of the Island. Summer plantings on the coastal plains usually develop yellows, a condition brought about by the general prevalence during these months of the bean leaf-hopper *Empoasca fabalis,* De Long. According to Wolcott (2) the injury to the plant is not only directly due to the feeding of the insects, but also to a yellows or mosaic disease which is transmitted by the leaf-hoppers from diseased to healthy plants. Late spring or summer plantings, if not destroyed by leaf-hoppers usually make a luxuriant vegetative development, but the yields are very low. However, during the winter months leaf-hoppers are rarely a major pest of economic importance.

Good drainage is of paramount importance to bean culture. Any prolonged excess of moisture provokes damping off, root rot, anthracnose, and chlorosis and retards growth. For this reason, beans are seldom seen planted in poor drained level fields.

During the war years many acres of sugar cane were successfully intercropped with beans as a result of a cooperative program of the Agricultural Adjustment Administration aimed to alleviate the food shortage in the Island. In order to qualify for benefit payments, cane growers were compelled to plant food crops to the extent of from 5 to 20 per cent of their total sugar cane acreage and not less than two-thirds of these food crops had to be legumes.

According to data obtained in prewar years by agents of the Extension Service of Puerto Rico covering eighteen bean producing districts of the Island, the cost of producing white beans ranged from $1.98 per hundred-weight in Guayama to $5.50 per hundred-weight in Manatí, and averaged $3.71 for all the districts reporting. At present these costs of production are more than double. Practically all the work, from planting to harvesting and hulling and cleaning the product for the market, is done by hand.

PREVIOUS WORK DONE

The earliest record known of work done in bean selection in Puerto Rico is obtained from a trial made in the year 1918 by McClelland (4) from the Puerto Rico Agricultural Experiment Station at Mayaguez where he made four trials, planting at different dates commencing on April 1st. The other planting dates were April 23, May 17 and June 18 of the same year. He used in these tests nineteen varieties from the United States, Santo Domingo, Venezuela and Puerto Rico. According to his results, the planting dates of these trials were considered too late for an assurance of best results with beans in that section of the Island. However, best results were obtained from Venezuelan black and Puerto Rican white beans.

During 1919 the bean selection work was continued by Snyder (3), Assistant in Plant Breeding of the Puerto Rico Experiment Station. His work was directed chiefly towards the selection of the black Venezuelan bean.

McClelland (5) in 1920 continued the work using more than forty distinct varieties. His tests showed as a general rule that, under favorable conditions, much greater dependence for a crop can be placed on varieties previously grown in the tropics than those imported from the continental United States. Both the Puerto Rican white bean and the Venezuelan black bean were notable for heavy yields.

In McClelland's (6) report for 1921, the bean tests again demonstrated the superiority of the varieties collected in the Caribbean region over the varieties imported from the North. Of the Caribbean varieties, the black and the white beans were the most prolific. Two extensive plantings of selections from the Venezuelan black were made at the Station to obtain a type as prolific as the Venezuelan and of a color acceptable to the local market.

During the year 1922 McClelland (7) obtained various white strains derived from a cross with black Venezuelan. In the report for 1923 made by McClelland (8) the black Venezuelan outyielded five of the white strains which were derived from a cross with the black Venezuelan. From 1923 on, the work with beans at the Mayaguez Agricultural Experiment Station was chiefly devoted to the stringless beans.

Undoubtedly some of the white strains of the Venezuelan black bean obtained at Mayaguez were distributed among farmers of the Island and have been mixed with the common native white beans.

MATERIAL AND METHODS

In order to isolate and test high yielding lines the major part of this work was divided into three main phases; namely, plant-to-row tests, preliminary tests, and advanced tests. For the plant-to-row tests the seed was obtained from single plant selections. At the beginning of the work these selections were made directly from the farmers' fields. This system had its drawbacks due to the fact that beans are grown in limited acreages and it was difficult to mark selections and then be present just before the farmer did the harvesting. Farmers usually pick their plants on one or two day's notice subject to weather conditions. Another disadvantage was that plants selected in farmers' fields generally did not produce enough seed to establish a plant-to-row test.

In view of these drawbacks, bean samples were collected from the crops already harvested from different farmers and localities. About 500 seeds from each sample were taken and planted five seeds to a hill at the Station's farm.

By progressive thinning of the weaker plants, a method of selection in itself, a one plant hill was finally left. From the remaining plants, selections were made for plant-to-row testing of the best yielders and of other characteristics considered of importance to the investigator. This method of plant-to-row testing is similar to the one described by Hardenburg (1) in his recommendations for the improvement of beans by selection.

As the plant-to-row test had to be done on level fields, for convenience it was necessary to provide ditches every 15 or 20 feet for adequate drainage. Ditches of about 1 foot in width and 8 inches deep proved to be satisfactory when made parallel to the plant rows. Another set of ditches running cross-wise, every 30 feet, and of the same size as those above mentioned, were opened to limit the length of the rows and to insure a better drainage. Within the ditched areas, five plant-to-row plots were established with two additional check rows along the sides.

Sixty seeds of each selection were planted, two seeds in every hill 1 foot apart in the row, to be thinned later to a single plant. The bean seed used for the check rows was obtained from a farmer who had grown it for over 20 years and who had carried accurate records in his farm. In some favorable seasons this stock yielded as much as 1,200 pounds per acre. The behavior of this seed in our trials has confirmed its high yielding qualities. In analyzing results of the plant-to-row test, the number of hills were counted and the yield based on 30 hills was found. The yield of the checks were similarly determined and the mean yields of the two checks rows was found. All selections yielding above the mean yield of the checks were entered into the preliminary tests.

In the preliminary tests the selections were replicated five or six times in $^1/_{100}$-acre plots. The planting distance bewteen rows was 2 feet. In the plant-to-row test, the distance between rows was 2½ feet, being larger in order to eliminate possible competition between high bush, low bush and climbing types. At the beginning the results of these preliminary tests were analyzed by Bessel's method to determine whether the differences in yield were statistically significant. However, in later trials the lattice and triple lattice designs described by

Cox (9) were used. These newer experimental layouts have proved to be well adapted to the testing of large number of varieties.

Only those selections demonstrating superior qualities in the preliminary tests were included in the advanced tests. The size of the plots were usually $^1/_{100}$ acre, but the number of replications were increased gradually as the number of varieties were reduced. The results of these tests were statistically analyzed by Student's or Fisher's methods. This was the technique followed during the first five years of this work. Later on Cox's (9) lattice designs were used until the number of outstanding selections were reduced to fourteen, when the randomized complete block design was used. The experimental layouts, in this case, were made following Capó's (10, 11) methods based on the assumption of a different effect constant for every pair of adjacent plots of a randomized block field trial, when an even number of plots has been used.

Besides these tests, other methods of approach were used in order to determine which other factors might also influence yield and quality in the selected varieties. Attempts were made to determine the best planting distances as well as the best planting season for the high yielding varieties. Chemical analyses and cooking tests were likewise performed in order to select for quality. In addition, the introduction of new varieties from other countries was also tried as another way of improving yield and quality.

As a general rule, fertilizer 10–10–5 or a similar analysis was applied in most of the bean tests at the rate of 1,000 pounds per acre.

EXPERIMENTAL DATA AND DISCUSSION

In the year 1936 when this work was started, 215 native white beans selections were included in a progeny test. Of this number, only 22 proved to be superior and they were included in an advanced test. According to the experimental data of the advanced tests performed during the winter of the year 1937, none of the selections were superior in yield to the check and all of them, therefore were discarded. During the year 1937 over 700 native white bean selections were tried in a preliminary test. Out of these 700 selections, 220 were chosen as superior and included in an advanced test.

During the years 1938, 1939, 1940, and 1941 the work with white bean selections was continued following the same steps outlined in the original project. Out of about 2000 white bean selections which were studied during these years, only three of them proved to be outstanding. These were selections 209, 1160 and 1250 and they were numbered accordingly as established varieties.

During the first year of the Second World War all efforts were focussed toward the propagation and distribution of these three promising varieties in order to help the serious food situation of the Island created by a shortage of shipping facilities for the importation of food products. About 5000 pounds of bean seeds from these superior white bean varieties were distributed directly to farmers, vocational schools, Farm Security Administration, Extension Service and other government agencies.

At the Isabela Substation a series of monthly planting trials were started early during the month of December, 1942 in which the selected variety 1160 was compared to a group of imported colored varieties and the native red bean. During the first days of each month a trial was established with five replicates for each of the following varieties: 1160, native red, Dominican Mottled, California Pink, Pompadour Mottled and Red Kidney. Though these tests were discontinued after eight successive monthly plantings, the results showed in general that the native white bean and the native red outyielded all the other imported varieties. These trials indicated that the best planting months for all bean varieties seemed to be December and April when the highest yields were obtained. The imported varieties Pompadour, Red Kidney and California Pink which came from higher latitudes of longer days, seemed to be adversely affected by the short photoperiod prevailing at the tropical latitude with short days in Puerto Rico. These beans had less plant development than the native varieties, bloomed and were harvested two to three weeks earlier, and showed more susceptibility to diseases and the effects of the damage caused by leaf-hoppers.

Another trial was planted at the Isabela Substation on March 7, 1942 using the native selected varieties 209, 785, 1160, 1250 and an imported white bean from Idaho. All of these varieties developed normally and produced heavily with the exception of the white bean from Idaho which bloomed very prematurely, the plants remained small and the production of grain was less than half the mean yield of the native varieties. Table I shows that the native varieties which yielded from 1195 to 1420 pounds per acre, were all superior to the imported Idaho bean which seemed to be affected adversely by the short days prevailing in the tropics. There were no significance differences in yield among the native varieties tested.

TABLE I—RESULTS OF A BEAN VARIETY TRIAL PLANTED AT THE ISABELA SUBSTATION ON MARCH 7, 1942

Variety	Type of Bean Color	Mean Yield of Ten Replicates (Pounds Per Acre)
209	White	1,225
785	Pink	1,420
1160	White	1,235
1250	White	1,195
Idaho White	White	555

Difference for significance at 5 per cent point: 308.

Several advanced trials under different seasonal and climatic conditions were established at the main Station and at the Isabela Substation during the period of 1941 to 1943 using the outstanding varieties 209, 785, 1160 and 1250. The combined results of these trials indicated again that there was no significant difference in yield among the varieties tested (Table II). However, these yields which ranged from 632 to 803 pounds per acre, are considered superior to the average yield of 472 pounds per acre reported for the island.

TABLE II—COMBINED RESULTS OF BEAN VARIETY TRIALS ESTABLISHED AT RIO PIEDRAS AND ISABELA (1941 TO 1943)

Variety	Type of Bean Color	Mean Yield (Pounds Per Acre)*	
		Rio Piedras Three Trials (Pounds)	Isabela Three Trials (Pounds)
209	White	803	692
785	Pink	737	803
1160	White	652	717
1250	White	632	676

*No significant difference between yields.

The pink bean 785 was originally selected from the mixed and unselected native bean for its high yielding characteristics. Unfortunately, farmers to whom this pink bean was distributed for further propagation, reported that this variety had poor cooking qualities. Furthermore, it was observed that this bean which was light pink when freshly harvested, turned to an undesirable dark brown color after placed under storage. Therefore, this pink bean was definitely discarded because of poor cooking qualities and undesirable color.

During 1944 a trial to determine the best planting distance for the superior bean varieties was established at Río Piedras. The superior varieties 209, 1160 and 1250 were tested together with a promising pink mottled bean introduced from Santo Domingo which was identified as A–37. Planting in drills 6 inches apart in 1 foot rows was compared with same planting method but with rows 24 inches apart. According to the results obtained as shown in Table III, the shortest distance between rows led to higher yields with various degrees of increase for the different varieties tested. By planting drills 12 inches between rows there an increase in yield of 15 per cent in variety 209, of 39 per cent in 1160, of 44 per cent in 1250 and of 59 per cent in variety A–37.

TABLE III—RESULTS OF A PLANTING DISTANCE TRIAL HARVESTED AT THE RIO PIEDRAS STATION (1944)

Variety	Yield (Pounds Per Acre)*		
	Drills 24 Inches Between Rows (Pounds)	Drills 12 Inches Between Rows (Pounds)	Increase in Yield (Per Cent)
A-37	580	920	59
209	800	920	15
1160	620	860	39
1250	320	460	44

*Mean yield from eight replicates for each variety which was planted at two different distances in each plot.

Chemical analyses were made of the white variety 1160 and of four of the red or pink varieties most commonly consumed in the Island. The results of these analyses are shown in Table IV. The white bean variety surpassed all the other colored varieties roughly by about 2 per cent in protein content. This variety was also slightly superior in

TABLE IV—CHEMICAL ANALYSIS OF SOME BEAN VARIETIES RIO PIEDRAS STATION (1944)

Variety	Water (Per Cent)	Protein (Per Cent)	Fat (Per Cent)	Carbohydrates (Per Cent)	Ash (Per Cent)	Fiber (Per Cent)
1160—Native white. .	12.42	24.62	1.75	65.11	4.63	3.84
Native red.	12.43	22.46	1.45	67.90	4.16	4.03
A-37, pink.	13.72	22.75	1.52	67.54	4.12	4.07
Pompadour, red	12.60	20.84	1.66	69.71	4.03	3.76
Red Kidney.	12.06	22.57	1.55	68.01	3.74	4.13

fats and mineral content and it ranked as the second lowest in fiber content.

Early in the fall of 1943 a trial based upon the triple lattice design was established at the Isabela Substation where 324 bean varieties and new selections were included. After this trial was harvested and statistically analyzed, 243 varieties and selections were discarded and 81 superior selections which yielded over 800 pounds per acre were retained for further trials. Several other trials using the lattice design were carried out at Isabela and at Río Piedras, some of them being planted simultaneously in both places. In this subsequent trials the 81 selections were reduced to 49 and these in turn to 14.

TABLE V—RESULTS OF FOUR BEAN TRIALS ESTABLISHED AT ISABELA AND RIO PIEDRAS (1944–45)

Variety	In the Eighty-one Variety Test at Isabela Nine Replications	In the Forty-nine Variety Test at Isabela Nine Replications (Pounds)	In the Fourteen Variety Test at Isabela Thirteen Replications (Pounds)	In the Fourteen Variety Test at Río Piedros Fourteen Replications (Pounds)
1302	515	1,129	845	1,594
1320	530	1,298	1,016	1,792
1329	459	1,129	985	1,512
1330	471	1,318	876	1,573
1350	453	1,149	791	1,492
1395	515	1,139	907	1,283
1404	505	1,127	849	1,379
1435	496	1,134	962	1,366
1595	601	1,159	965	1,668
1632	462	1,176	925	1,609
1682	501	1,220	900	1,291
1684	504	1,210	894	1,451
1722	464	1,281	837	801
1724	518	1,220	959	1,348

The statistically superior varieties in the two last trials were: 1320, 1329, 1395, 1435, 1595, 1632 and 1724.

The summarized results of these trials are indicated in Table V where only the fourteen superior selections with their permanent variety numbers are shown with the yields obtained in each test. It should be pointed out that the former superior varieties 209, 1160 and 1250 do not appear in this table because they were outyielded by several of the new superior varieties. From these series of trials the following seven superior varieties were selected: 1320, 1329, 1395, 1435, 1595, 1632 and 1724.

Two variety trials were established simultaneously at Isabela and Río Piedras during the month of May 1945 using the seven outstanding bean varieties and as check a native unselected white bean obtained from the interior town of Adjuntas. This was an off season planting with no fertilizer application which accounted for the low yields obtained. However, the results as shown in Table VI, serve to point out clearly the degree of success attained so far in this selection work, since even at such low levels of production, the native unselected bean was outyielded by the new selected varieties.

TABLE VI—RESULTS OF BEAN TRIALS AT ISABELA AND RIO PIEDRAS (1945)

Varieties	Mean Yield (Pounds Per Acre)	
	Isabela Fourteen Replications Planted May 7, 1945 (Pounds)	Río Piedras Sixteen Replications Planted June 1, 1945 (Pounds)
1320	260	425
1329	304	349
1395	308	351
1435	374	444
1595	265	360
1632	335	393
1724	267	376
Unselected native bean from Adjuntas	217	295

Difference for significance:
At the 5 per cent point ... 85 pounds
At the 1 per cent point ... 113 pounds

As fall plantings, two trials were again established in 1945 at Isabela and Río Piedras using the new seven outstanding varieties together with the former superior varieties 1160 and 1250. The trial at Isabela was seriously damaged by excessive rainfall during the month of November and consequently no reliable data could be gathered. However, the trial at Río Piedras was successfully harvested and its results are presented in Table VII. With the exception of variety 1724, most of the new varieties outyielded by a narrow margin the varieties 1160 and 1250. Furthermore, the highest yielder was variety 1632 which with 889 pounds per acre surpassed statistically varieties 1250, 1435 and 1724.

TABLE VII—YIELD AND CHEMICAL ANALYSIS OF NINE OUTSTANDING BEAN VARIETIES TESTED AT RIO PIEDRAS (1945)

Variety	Yield* Per Acre (Pounds)	Water (Per Cent)	Protein (Per Cent)	Fat (Per Cent)	Carbohydrates (Per Cent)	Ash (Per Cent)	Fiber (Per Cent)
1632	889	15.23	21.70	1.30	53.58	4.34	3.85
1595	852	13.94	26.71	1.53	50.45	3.71	3.66
1320	850	13.53	25.37	1.47	51.89	3.87	3.87
1395	842	13.25	26.07	1.44	51.47	3.94	3.83
1329	834	14.19	26.79	1.51	50.75	3.54	3.22
1160	767	12.42	24.62	1.75	65.11	4.68	3.84
1250	738	12.67	23.50	1.56	67.01	4.12	3.81
1435	734	13.33	26.85	1.36	51.11	3.60	3.75
1724	586	14.94	23.95	1.17	52.52	4.08	3.34

*Difference for significance:
At 5 per cent point—132.
At 1 per cent point—174.

A qualitative study was also undertaken in order to select the best varieties from such a group of nine outstanding varieties which did not differ widely in their yields. According, chemical analyses and cooking tests[1] were made in order to discard those varieties of undesirable qualities. The results of the chemical analyses as shown also in Table VII, indicate some variation in the contents of protein, fat, carbohydrates, minerals and fiber. Taking this information together with the results of the cooking tests made by the Home Economics Division of the Extension Service, it was possible to make a final reliable selection. The report of the cooking tests indicated that variety 1329 was the most tender and of better cooking qualities. Next to that variety were numbers 1395 and 1632. In these tests the other six varieties proved to be somewhat harder but as to palatability, they were similar to the most tender types when thoroughly cooked.

Out of these superior varieties resulting from the cooking tests, number 1329 outranked the others with the highest protein and fat content, and the lowest fiber percentage. This variety and 1632 which had been a consistent high yielder in several trials, were finally selected as the best for propagation and distribution upon the successful completion of this bean improvement work.

Summary and Conclusions

The average yield of our native unselected white bean which amounts to 472 pounds per acre, is considered very low when compared with the yields obtained in the bean growing regions of the United States. After ten years of systematic selection and field experimentation with this white bean, varieties were selected which showed a remarkable improvement in yield over the native stock.

During the first phase of this work in which more than 3,000 bean strains were studied, varieties 209, 1160 and 1250 were selected for their high yield and other desirable characteristics.

Out of 324 new strains studied during the second phase of this project, the following seven varieties proved to be superior to variety 209 previously selected: 1320, 1329, 1395, 1435, 1595, 1632 and 1724. Variety 1632 outyielded also variety 1250 which had been selected in the first phase of this work.

Final yield trials were made with the nine best white bean varieties selected. Chemical analysis and cooking tests were also performed with these selected varieties. Accordingly, varieties 1329 and 1632 resulted among the best for their high yield and their superior cooking qualities. Variety 1329 analyzed 26.79 per cent protein, the second highest found in all of these varieties. On the other hand, this variety had only 3.22 per cent fiber, the lowest among the varieties tested. Both characteristics seem to enhance quality in this high yielding variety.

Other chemical analyses showed that native white beans have a higher protein content than native red or imported colored beans.

Varieties 1329 and 1632 have been extensively propagated by this

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[1] The authors are grateful to Mr. F. J. Marchán, Assistant Chemist of the Animal Husbandry Department for the chemical analyses of the bean varieties and to Dr. Esther Seijo, Assistant Director Extension Service in Charge of Home Demonstration Work, for the cooking test.

Station and over 8,000 pounds have been distributed to farmers throughout the Island.

Though only one trial was performed, it seemed that by reducing planting distances from drills 24 inches apart to drills 12 inches between rows, marked increases in yields could be obtained with different bean varieties.

Taking into consideration the results of the numerous trials performed, in general, the selected varieties outyielded the unselected native bean and the imported varieties by amounts which fluctuated from 30 to over 100 per cent. The imported varieties California Pink, Idaho White, Pompadour and Red Kidney which had very low yields, seemed to be affected by the short photoperiod prevailing in the tropics. These varieties seemed to be also more susceptible to diseases and to the leaf-hopper *Empoasca fabalis.*

Observations made, showed that in the northern section of the Island better yields were obtained when beans were planted early during the months of April and December. Beans planted during the summer months were subject to heavy losses or to complete failure due, either to the excessive rains, or to the increased damage caused by leaf-hoppers in the short dry spells with warm weather which prevail during the season.

It seems that the long, warm and moist days in the summer months tend to reduce materially the yield in beans. Under such conditions the plants have a tendency to grow tall and to develop twining or climbing characteristics, flowering is scanty and consequently, few pods set.

Regardless of season, excessive rainfall after the pods are well formed or beginning to dry, causes the development of pod diseases and the premature sprouting of seeds inside the pods, thus reducing yields considerably. Good drainage is of paramount importance in bean culture since any prolonged excess of moisture is liable to cause serious damage to the crop.

Although no trials have been carried to the effect, it is claimed that in the southern dry section of the Island the best planting time is from August to November, as determined by the time when they have the benefit of the rains in that area. In the mountainous regions of the interior towns, beans grow well when planted in the spring or autumn months, showing a wider range of adaptability. In all cases dry warm weather favors the development of leap-hoppers which cause curling of the leaves and stunting of plants with its consequences of crop reduction or probable failure.

Although the native selected varieties are comparatively resistant to the attacks of leaf-hoppers, chemical insecticides should be used also to help in its control or prevention.

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The Effects of Temperature on Losses in Sweetpotatoes

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Although cured sweetpotatoes are stored commercially to extend their marketing period, the length of time a crop can be successfully stored depends on several factors, one of which is proper temperature. During the storage period it is customary to allow the temperature to fluctuate between satisfactory limits rather than to store the roots at a constant temperature. However, in order to recommend a satisfactory range of temperatures suitable for the commercial storage of this crop the optimum temperature should be determined as well as the limits of the temperature range that is permissible. Since the full effects of storage temperature on the keeping quality of sweetpotatoes are usually not apparent after 1 or 2 months' storage, and since the crop is generally stored longer than this, only data taken after 3 or 4 months' holding are presented.

The tests on sweetpotatoes reported here were made to determine (a) the effects of waxing, (b) the influence of storage temperature on keeping quality, and (c) the tolerance of injured and uninjured, noncured roots to temporary exposure to specified low temperatures.

The term "keeping quality" as used here refers to the inherent tendency or ability of sweetpotatoes to remain sound and otherwise desirable for human consumption. In this paper the evaluation of keeping quality of the roots as affected by different storage temperatures is based principally on the amount of decay. However, color, and in the case of cooked material, flavor as well, are extremely valuable indexes of consumer acceptability that were also considered in judging keeping quality.

LITERATURE

In much of the literature on the storage of cured sweetpotatoes recommendations for the proper storage temperature or range in temperatures have not been accompanied by experimental data. The storage temperature recommendation in the publications reviewed and the number of these recommending each set of conditions are as follows: "not below 50 degrees F", four publications; "about 50 to 60 degrees F," one; "between 50 and 60 degrees F," one; "about 55 degrees F," two; "55 degrees F," three; "about 55 to 60 degrees F," two; and "55 to 65 degrees F," one.

Lutz (1) found that culinary quality was adversely affected when cured sweetpotatoes were held for 4 to 4½ months at a constant temperature of 50 degrees F. Cooley confirms this bad effect from 50 degrees' storage and also reports the more serious trouble of hard spots in the roots after 7 months' storage at this temperature, and further discoloration and impaired flavor when certain of the varieties were cooked (2).

Lutz (1) and Kimbrough (3) have stated that cured sweetpotatoes withstood exposure to low temperature better than noncured ones. In exposing cured sweetpotatoes to low temperatures Lauritzen (4) found that "Chilling injury . . . may or may not be evident at the end of the chilling period" and that "such signs of injury may become evident after a period of storage even in a temperature favorable to sweetpotatoes." Lauritzen did not work with noncured sweetpotatoes as was the case in the low-temperature tests reported here.

WAXED VS. NOT-WAXED ROOTS

The logical answer to the question of whether the waxing of sweetpotatoes is beneficial cannot be based entirely on moisture loss from the roots as waxing may influence decay or cause other forms of deterioration. The total loss in weight, including that due to decay, is a much more acceptable criterion for judging the effects of waxing and also the effects of different temperatures on the keeping quality of the roots.

Immediately after digging, the three varieties of sweetpotatoes reported in Table I were cured for 10 days at about 85 degrees F. For the first 3 days of the curing period the relative humidity was 90 per cent but in order to minimize sprouting it was then lowered to 70 to 75 per cent. The sweetpotatoes were cured and stored in filled bushel baskets. Before storing at 50, 55, 60, and 70 degrees the roots in half the number of baskets were carefully handled while being waxed with Brytene 333–B in the proportion of 1 part of wax to 4 parts of water. The relative humidity of each of the storage rooms was about 82 per cent.

TABLE I—LOSSES * ** IN WAXED AND NOT-WAXED CURED SWEETPOTATOES AFTER 3 MONTHS AT DIFFERENT TEMPERATURES

Storage Temperature (Degrees F)	Not Waxed						Waxed					
	Porto Rico		Vineland Bush		Yellow Jersey		Porto Rico		Vineland Bush		Yellow Jersey	
	Loss in Weight* (Per Cent)	Loss in Weight Including Decay** (Per Cent)	Loss in Weight (Per Cent)	Loss in Weight Including Decay (Per Cent)	Loss in Weight (Per Cent)	Loss in Weight Including Decay (Per Cent)	Loss in Weight (Per Cent)	Loss in Weight Including Decay (Per Cent)	Loss in Weight (Per Cent)	Loss in Weight Including Decay (Per Cent)	Loss in Weight (Per Cent)	Loss in Weight Including Decay (Per Cent)
50	12.2	92 0	13.0	64.8	12.0	37.4	11.2	82.6	12.4	91.5	9 6	54.5
55	9.5	16.8	8.8	24.0	7.7	13.9	8.7	32.7	7 7	33.4	6.9	18.0
60	7.2	30.7	7.5	28.0	13.5	16.7	6.4	28.0	5.4	44.2	6.2	11 0
70	24.2	45.6	19.5	42.3	29.6	59.2	23.6	34.3	21.4	46 3	33.0	55 0

*Respirational and transpirational losses in weight of sound and decayed roots.
**Losses described in footnote 1 combined with the weights of the decayed roots.

Table I shows on a percentage basis, the loss in weight in the sound and decayed roots after 3 months' storage and also this loss combined with the weight of the decayed specimens. In 10 out of 12 cases (three varieties) the loss in weight was less in those that had been waxed, but the differences in weight loss between the waxed and not waxed roots were small. Seven of the 12 comparisons between the waxed and not waxed roots showed a greater total loss in weight (including decay) in the waxed roots.

In both the waxed and not waxed lots of all three varieties (Table I) the smallest total losses occurred in the roots held at 55 and 60 degrees F. In the not waxed roots 55 degrees proved to be a slightly better storage temperature than 60 degrees, which was also true of the waxed Vineland Bush variety. In the Porto Rico and Vineland Bush varieties the combined loss in weight and decay values are considerably higher at 50 than at 70 degrees, indicating that for these varieties the former temperature was less desirable than the latter. There was little choice between 50 and 70 degrees in the case of the Yellow Jersey variety. That the loss in weight at 50 degrees (Table I) was usually higher than at 55 or at 60 degrees was due to the greater amount of decay at the former temperature.

INFLUENCE OF STORAGE TEMPERATURE ON COLOR, FLAVOR AND DECAY

All of the storage lots listed in Table II had the same pre-storage and storage treatments as those described previously. On inspection after 3 months' storage five specimens of each variety from each temperature were cut crosswise and the color was noted during and after a 30-minute exposure to the air; another five specimens from corresponding lots were cooked by steaming for 40 minutes without pressure and the color was noted as in the uncooked sample.

As shown in Table II, 50 degrees F had a deleterious effect on the color of the raw roots and also on the color and flavor of the cooked product (2). The roots stored at 55 and 60 degrees were slightly discolored in some instances when cut raw but when cooked were in general of very good color and flavor. At 70 degrees the color of the raw roots, when cut, varied from "slightly discolored" to "good," but a pithy breakdown was noted in all varieties. The cooked roots in all varieties from this temperature were of fair flavor, but in some cases showed slight bronze-green discoloration.

In another test Porto Rico, Nancy Hall, Vineland Bush, and Yellow Jersey sweetpotatoes were dug and held in filled bushel baskets at 70 degrees F for 28 days with a relative humidity of 85 per cent. These were then stored at 50, 55, 60, and 70 degrees, 1 bushel at each temperature. After 4 months' storage at these temperatures, the amount of decay was as follows (given in the same order as the temperatures listed above): Porto Rico, 81, 63, 45, and 52 per cent; Nancy Hall, 100, 31, 0, and 1 per cent; Vineland Bush, 100, 28, 38, and 36 per cent; and Yellow Jersey, 90, 12, 34, and 11 per cent. Decay was most severe at 50 degrees with no significant difference between the other temperatures. However, the data show considerable differences between varieties.

EXPOSURE OF NON-CURED ROOTS TO LOW TEMPERATURES

During the commercial handling of sweetpotatoes in the fall the freshly dug crop may be exposed to unfavorable low temperatures that often prevail at this time of year. In order to determine the effects of such exposure on the keeping quality of the roots two tests were set up to simulate handling under low temperature conditions.

TABLE II—Condition of Raw and Cooked, Cured Sweetpotatoes After 3 Months' Storage (Uncooked) at Various Temperatures

Porto Rico		Nancy Hall		Vineland Bush		Yellow Jersey	
Raw	Cooked	Raw	Cooked	Raw	Cooked	Raw	Cooked
Storage Temperature—50 Degrees F							
Severely discolored	Severely discolored — Flavor slightly bitter	Severely discolored	General darkening — Flavor poor	Slightly discolored	Dark ring ¼ inch below cortex — Flavor poor	Slightly discolored	General darkening — Flavor poor
Storage Temperature—55 Degrees F							
Slightly discolored	Mottled discoloration — Flavor fair	Slightly discolored	Half the number of roots somewhat darkened — Flavor fair to good	Color good	Color good Flavor good	Color good	Color good Flavor good
Storage Temperature—60 Degrees F							
Slightly discolored	Small discolored spots — Flavor good	Color good	Color good Flavor good	Color good	Color good — Flavor good to excellent	Color good	Color good — Flavor good to excellent
Storage Temperature—70 Degrees F							
Slightly discolored — Breakdown	Small discolored spots — Flavor fair	Color good — Breakdown	Color good — Flavor fair	Color good — Breakdown	Slightly discolored — Flavor fair	Color good — Breakdown	Slightly discolored — Flavor fair

The first test was made to approximate the low temperature environment that may obtain in transit when noncured sweetpotatoes are shipped immediately after digging or are left either in the field or in an exposed shed for 3 to 10 days before shipment. The 5-day holding period at 70 degrees F was to approximate conditions on the market. Half of the Big Stem Jersey roots used in this test were rather severely skinned and bruised by striking them several times on the edge of a basket, and half of them were carefully dug and handled. Eight filled bushel baskets of roots, four of which were injured and four not injured, were exposed to each of the following temperatures, 30, 32, and 40 degrees. From each temperature a bushel of injured and a bushel of uninjured roots were removed after 3, 5, 7 and 10 days. After removal from these temperatures the roots were held at 70 degrees for 5 days. Decayed roots were then sorted out and the weights recorded. Fig. 1 shows the decay to be greatest in those held at 30 degrees, intermediate at 32 degrees, and lowest at 40 degrees, and that at each of the exposure temperatures the injured roots decayed to a greater extent than did the uninjured ones. Unchilled sweetpotatoes were stored for 15 days at 55 degrees and at 70 degrees for comparison with those exposed to the lower temperatures. At 55 degrees the injured roots showed 54 per cent decay and the uninjured 2 per cent;

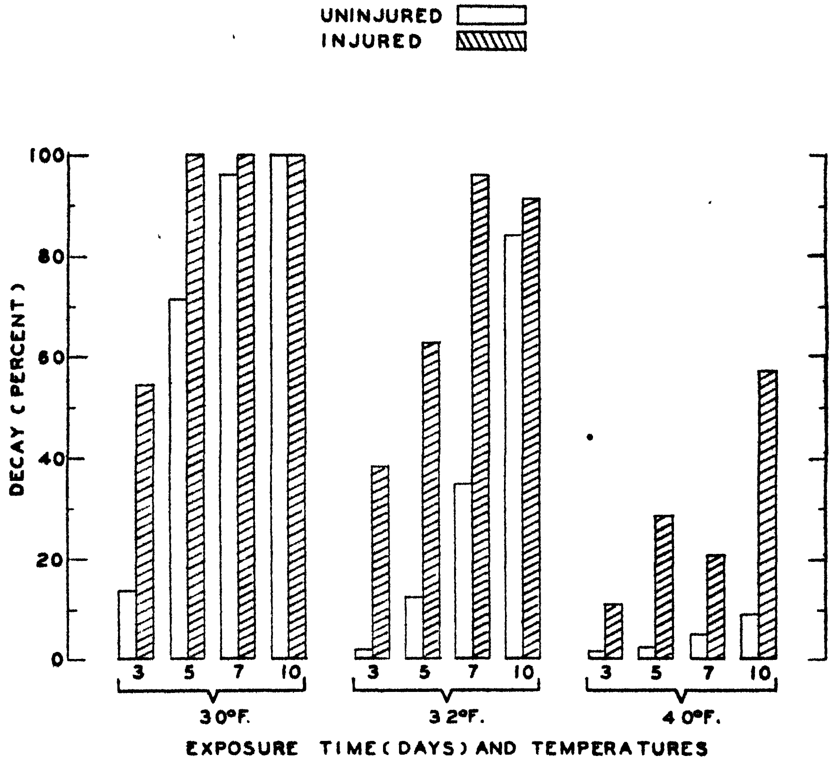

FIG. 1. Percentage of decay in noncured Big Stem Jersey sweetpotatoes after exposure to 30, 32, and 40 degrees F for 3, 5, 7, and 10 days at each temperature, each lot having been held for 5 subsequent days at 70 degrees.

at 70 degrees the injured showed 14 per cent and the uninjured none. These results clearly bring out the bad effect of skinning and bruising on the keeping quality of noncured sweetpotatoes at these temperatures.

In another test 3 barrels of noncured, uninjured Big Stem Jersey sweetpotatoes were thoroughly mixed and 1 barrel put at each of the following temperatures, 32, 40, and 50 degrees F. After 13 days at these temperatures the decay in these barrel lots was 6, 35, and 43 per cent, respectively. In order to determine the full effect of exposure to these temperatures a bushel basket of selected, sound roots from each barrel lot was then put at 70 degrees. After 9 succeeding days at 70 degrees the decay amounted to 100, 78, and 19 per cent in those stored previously at 32, 40, and 50 degrees, respectively. These results show that 50 degrees for the first 13 days after digging was harmful since considerable decay was prevalent in this lot. They also show that, whereas 32 degrees controlled decay well (and 40 degrees controlled it to a less degree) for the first 13 days, the exposure to these temperatures had a marked, deleterious effect on the keeping quality of the surviving, nondecayed roots when these were subsequently held at 70 degrees.

SUMMARY AND INTERPRETATIONS

The following statements are based on the results of these experiments:

1. The wax treatment was of no benefit in experimental lots of sweetpotatoes held for as long as 3 months.
2. Decay was usually less at storage temperatures of 55 and 60 degrees F than at either 50 or 70 degrees.
3. Internal discoloration in raw sweetpotatoes was less in amount in those stored at 55 and 60 degrees F than in those held at either 50 or 70 degrees. Color and flavor of the cooked roots were more desirable in the lots stored at 55 and 60 degrees.
4. Noncured, uninjured Big Stem Jersey sweetpotatoes tolerated 3 days' exposure at 30 degrees F, 5 days at 32 degrees, or 10 days at 40 degrees without very serious development of decay after a short (5-day) subsequent holding period at 70 degrees. In contrast with this are the results of the test in which roots held for 9 days at 70 degrees showed the harmful effects of a previous 13-day exposure to 32, 40, or 50 degrees.
5. Skinning and bruising of noncured sweetpotatoes increased the decay at temperatures ranging from 30 to 70 degrees F.
6. Since our best results were obtained with cured sweetpotatoes held at 55 and at 60 degrees F it appears that a range between these two temperatures would be best for commercial storage.

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Studies on Possibilities and Limitations of the Seed Piece Method of Planting Sweetpotatoes

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THE usual method of growing sweetpotatoes in this country involves considerable expense in preparing and caring for plant beds as well as in pulling the "draws" or plants and in setting them in the field. It also necessitates late planting of a considerable proportion of the acreage since, unless an unusually large number of roots are bedded, too few plants are produced at one time to set the average grower's entire acreage. Planting pieces of sweetpotato storage roots in a manner similar to that used in planting Irish potatoes has sometimes been recommended. If successful, such a method of propagation should eliminate the usual plant bed costs and permit more uniformity in time of planting than the conventional method allows, and thus should avoid some of the low yields common in late plantings. In order to determine the possibilities and limitations of such a seed piece method as compared with the usual method of propagation, experimental work was undertaken at the U. S. Horticultural Field Station, Meridian, Mississippi, in the spring of 1942 and was continued during three seasons.

While these studies were in progress the Georgia Coastal Plain Experiment Station published a report recommending the use of the seed piece method in producing sweetpotatoes for livestock feed but not for table use (2). Among its suggestions for securing best results by this method were the following: use of the Porto Rico variety, planting on well-drained soil, planting tip and stem end seed pieces, treating seed pieces with mercuric chloride, and planting in a shallow furrow 1 to 2 inches deep. Recently Nunn (3) has reported a number of cases where the seed piece method was used with good results as well as some where the results were poor.

EXPERIMENTS DURING SEASON OF 1942

Materials:—Roots of the Porto Rico variety averaging about 0.25 pounds in weight and 1½ inches in diameter which had been held over winter in standard storage, were used. The field soil on which the plantings were made was a well-drained Ruston fine sandy loam to which 1000 pounds per acre of 4–10–7 fertilizer was applied.

Methods:—Roots in sufficient numbers to insure adequate planting material were cut into seed pieces of two types: (a) 1-inch lengths unsplit; (b) 2-inch lengths split in half longitudinally. (Small ends of all roots were discarded to avoid all very small seed pieces). One-half of the material of each of the two seed piece types was cured by holding the seed pieces for one week just prior to planting in a room maintained at 85 degrees F and approximately 80 per cent relative humidity. Lots to be cured were prepared immediately before the curing period, all others were prepared just before planting time. Immediately before planting one-half of the material of each of the cured and uncured lots of the two seed piece types was treated with mercuric chloride by immersing in a 1 to 1000 solution for 10 minutes.

Four plantings made on March 20, April 10, May 1, and May 20 constituted the main plots in each of three blocks in a split-plot field experiment. Each of the main plots was subdivided into nine randomized, 25-foot, single-row subplots, each planted with one of the eight seed piece types described above or with plants of the control treatment. Plants or seed pieces were spaced 12 inches apart in rows 4 feet apart. The seed pieces were planted in furrows 2 to 3 inches deep and then were covered with 4 to 5 inches of soil. The control treatment consisted in bedding whole roots (after immersing for 10 minutes in 1 to 1000 mercuric chloride) in the regular manner in an open field at the time the seed pieces were planted and subsequently setting the resulting plants, when they had attained sufficient size, in the designated field subplots. "Skips" resulting from failure of seed pieces to sprout or from death of plants, were not replanted. Data were analyzed by the Variance Method.

Results:—The various treatments and the resulting yields are shown in Table I.

TABLE I—INFLUENCE OF PLANTING DATE AND SEED PIECE TREATMENT ON TOTAL YIELDS OF PORTO RICO SWEETPOTATOES — 1942

Treatment Number	Longitudinal Splitting of Seed Pieces*	Curing	Treatment With Mercuric Chloride**	Yield Per Acre (in Bushels) When Planted on				
				Mar 20	Apr 10	Apr 30	May 20	Means for Four Planting Dates†
1		Control		343	358	274	198	293
2	None	None	None	92	182	102	87	116
3	Split	None	None	87	172	134	137	132
4	None	1 week in spring	None	202	184	121	88	149
5	Split	1 week in spring	None	292	320	140	169	230
6	None	None	Treated	111	154	111	116	123
7	Split	None	Treated	107	234	100	117	154
8	None	1 week in spring	Treated	250	186	59	99	148
9	Split	1 week in spring	Treated	242	226	127	129	181
Means for nine treatments†				192	224	130	133	--

*Seed pieces were cut to 1-inch lengths when not split, and 2-inch lengths when split in half longitudinally.

**Cut pieces treated immediately before planting.

†Differences required for significance (5 per cent point); between treatments (mean of 4 planting dates), 49; between planting dates (mean of 9 treatments), 39.

A fairly good stand (80 per cent or better) was obtained with all treatments except with the two earliest plantings of treatments 2 (not split) and 3 (split) in which the pieces were not cured or treated with mercuric chloride and with the earliest planting of treatments 6 and 7 (not split and split seed pieces treated with mercuric chloride but not cured). During the curing of the untreated cut seed pieces about 30 per cent were lost by decay because of the large amount of freshly cut surface through which decay organisms could enter. In supplementary studies it was found that this decay could be almost entirely eliminated by treating the seed pieces with mercuric chloride just before curing.

Each of the seed piece treatments produced a significantly smaller yield than the control treatment. In all cases when the four planting dates were averaged yields were higher (but not always significantly so) when the seed pieces were split longitudinally than when they were not. Curing the seed pieces resulted in higher (but not always significantly higher) yields than were obtained from comparable pieces not cured. With non-cured pieces, treatment with mercuric chloride resulted in slight but not significant increases in yields.

The percentage of marketable sweetpotatoes was higher when plants were used than when seed pieces were planted. Part of this was due to unmarketable "mother" potatoes (Fig. 1) being produced as a result of direct growth of the seed pieces. More "mother" potatoes were produced when the seed pieces were split longitudinally than when not so split. The weights of the "mother" potatoes amounted to from 10 to 20 per cent of the total yields in the plots where seed pieces were planted.

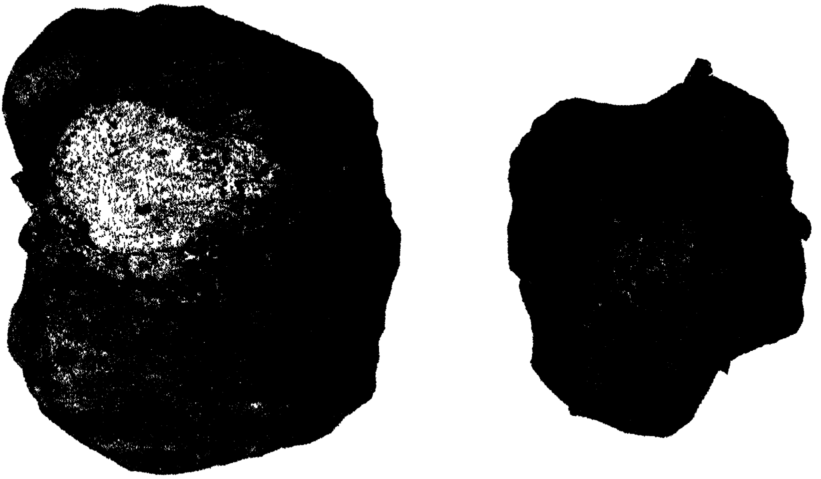

FIG. 1. Two "mother" sweetpotato roots resulting from growth of root seed pieces. Left, from a seed piece split longitudinally — Note cut side of original seed piece near center; right, from an unsplit seed piece.

Highest yields were usually obtained when the seed pieces were planted (or roots bedded) on April 10. Later plantings resulted in very marked reduction in yields. Differences between the March 20 and April 10 yields were not consistent among the several treatments used in the test.

EXPERIMENTS DURING SEASON OF 1943

Materials:—In addition to Porto Rico roots, those of the variety Triumph were included in 1943. The Porto Rico roots were 1 to 1½ inches in diameter and weighed about .15 pound each while the Triumph roots were 1 to 2 inches in diameter and averaged about 0.3 pounds. The field plantings were made on the same soil type as that used in 1942, fertilized with 1000 pounds of 2–8–8 per acre.

Methods:—Each root of both varieties was cut into 4 approximately equal-sized seed pieces in one of two ways: (a) by cutting into transverse sections only; (b) by cutting through the middle transversely then splitting through the middle longitudinally. Approximately one-third of the required number of seed pieces of both types and varieties were cut just after harvest in the fall of 1942 then were cured 10 days at 85 degrees F and 80 per cent humidity before storing until planting time in the spring. A second one-third of the seed pieces were cut and cured in the same manner just before planting time. The remainder were planted uncured. All seed pieces were treated for 10 minutes with mercuric chloride solution either immediately before curing, or in the case of those not cured, just prior to planting. The two varieties were used as the main plots in the split-plot field arrangement in four randomized blocks. Each main plot was subdivided into seven 50-foot, single-row, subplots each of which was planted with one of the six treatments of seed pieces or with control plants of the type used in 1942. Plants or seed pieces were spaced 12 inches apart in rows 4 feet apart.

Results:—Data for the per cent stand of plants and total yields obtained with the several seed piece treatments are shown in Table II.

TABLE II—INFLUENCE OF SEED PIECE TREATMENT ON TOTAL YIELDS OF SWEETPOTATOES — 1943

Treatment Number	Longitudinal Splitting of Seed Pieces	Curing	Stand* (Per Cent)			Total Yield Per Acre (Bushels)**		
			Porto Rico	Triumph	Mean of Both Varieties	Porto Rico	Triumph	Mean of Both Varieties
1	Control		84	86	85	338	361	350
2	None	Fall	25	45	35	143	207	175
3	Split	Fall	22	33	28	127	173	150
4	None	Spring	42	44	43	132	213	172
5	Split	Spring	34	46	40	124	174	149
6	None	None	36	34	35	154	176	165
7	Split	None	40	36	38	127	248	188

*Difference between treatments required for significance (5-per cent point). mean of both varieties 9.

**Difference between treatments required for significance: mean of both varieties, 67.

The per cent stand and total yields were decidedly lower for all the seed piece treatments than for the control in which plants were planted in the usual manner. A rather high percentage of the seed pieces cut and cured in the fall decayed during the winter months, making that method of preparation a rather impractical one. The reductions in yield resulting from the seed piece method were relatively greater in the Porto Rico variety than in Triumph. In contrast with the 1942 results, in all but one case lower yields were obtained where the seed was split than where it was not. There was no apparent consistent effect in the use of curing on either the stands of plants or yields. No consistent differences in production of "mother" potatoes were found between split and non-split seed piece methods.

EXPERIMENTS DURING SEASON OF 1944

Materials:—Porto Rico, and Triumph roots of essentially the same sizes and weights as those employed in 1943 were used in 1944. Field plantings were made on Ruston loamy sand, a well-drained soil, fertilized with 600 pounds per acre of 4–8–8.

Methods:—Roots were cut into an average of four pieces each and these pieces were treated with mercuric chloride just prior to planting or, in the case of cured lots, just prior to the 10-day curing period immediately preceding planting. Two lots of each variety were planted without curing: in one only the pieces from the proximal and distal ends of the roots were planted; in the other all pieces from the entire roots were used. The cured lot of each variety also contained all pieces from the entire roots. These three seed piece treatments and the controls (same as used in the other two seasons) were arranged in two 4 x 4 latin squares — one for each variety. Single rows 50 feet long constituted the individual plots. Spacings between and within rows were the same as the two preceding seasons except that the Triumph variety seed pieces or plants were spaced 18 inches apart in the rows.

Results:—Stand and yield results for this test are shown in Table III.

TABLE III—INFLUENCE OF SEED PIECE TREATMENT ON PER CENT STAND, YIELD OF "MOTHER" ROOTS AND TOTAL YIELD OF SWEETPOTATOES — 1944

Treatment Number	Portion of Root Used	Curing of Seed Piece	Stand (Per Cent)		Yield of "Mother" Roots Per Acre (Bushels)		Total Yield Per Acre (Bushels)	
			Porto Rico	Triumph	Porto Rico	Triumph	Porto Rico	Triumph
1	Control		88	96	0	0	213	238
2	Ends only	None	50	72	11	15	141	207
3	Entire root	None	44	66	8	5	138	187
4	Entire root	10 days in spring	41	71	9	13	149	235
Difference between treatments required for significance (5-per cent point)			11	11	7	10	38	---*

*Difference between treatments not significant.

All of the seed piece treatments resulted in poorer stands than the control treatment. These reductions were less for Triumph than for Porto Rico. No significant differences were found in per cent stands or total yields among the various seed piece treatments with either variety. All of these treatments resulted in significantly lower yields than the control with the Porto Rico variety and lower than the control, though not proven to be significantly so, with the Triumph. In each case between 3 and 8 per cent of the total yields resulting from seed piece propagation were made up of "mother" roots.

DISCUSSION AND SUMMARY

In each of 3 years the use of seed pieces resulted in much lower yields in the Porto Rico variety than were obtained from the control treatment which consisted in setting plants obtained from roots bedded in the open at the same time the seed pieces were planted in the field. In 1 year much lower yields were obtained from Triumphs planted from seed pieces than from the control treatment while in a second year the yields from seed pieces were lower than the control although not proven to be significantly so.

In these tests stands resulting from seed piece propagation were almost invariably poorer than those obtained from the control method.

Longitudinal splitting of seed pieces did not prevent development of "mother" potatoes from the seed pieces themselves.

Using only the ends of roots appeared, in these trials, to have little if any advantage over using all seed pieces cut from the entire "seed" roots. The latter method makes better use of the propagation roots since approximately twice as many would be required to plant a given area if only the ends were used.

In all of the present trials weed control was a serious problem in the plots in which seed pieces were planted. The plants did not emerge uniformly and it was difficult to keep the weeds under control during the long periods required for all of the plants to come up. Weeds probably could be controlled early in the season by going over the entire field with a peanut weeder as suggested by the Georgia Coastal Plain Experiment Station (*2*), a rotary hoe, or a spike-tooth harrow. Even if some of the young plants were broken, new ones would develop from the unbroken stems below the soil surface or from the seed pieces.

The seed piece method might be of some value to farmers who were unable or did not desire to grow plants in the conventional manner, for producing sweetpotatoes for stock feed with a variety such as Triumph. Under conditions such as prevailed during these experiments, the reductions in yields with the Porto Rico variety from the seed piece method were so great as to indicate the impracticability of using this method with this variety. Even with the Triumph variety consistent reductions in yields could be expected under these conditions. Work of Anderson, Randolph, and others (1, 4) has shown that if sweetpotatoes are grown for stock feed the cost and trouble of producing and setting plants in the conventional manner can be reduced by using mechanical transplanters and by using wider spacings of plants in the rows. It seems quite probable that any reductions in yields from use of such procedures would be less drastic than those resulting from the seed piece propagation method, at least under conditions such as those existing during the present experiments.

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The Effect of Nitrogen, Phosphate, and Potassium on the Yield of Red McClure Potatoes as Determined by Soil Analysis and Fertilizer Application[1]

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EVERY farmer would like to be able to determine by chemically testing a sample of soil in a field, just how much and what kind of fertilizer elements should be added to the soil for the best economic production of a particular crop. After many years of intensive research along this line, the problem has been only partially answered. Experience with growing plants is still the best source of information upon which to base the particular fertilizer needs of a given soil. Chemical information is frequently a distinct aid in the diagnosis of the needs of a soil, but if growers were dependent upon laboratory data alone, the results often would be disappointing.

Most "quick-test" methods of soil analysis have been worked out on soils having an acid reaction; consequently there is some doubt as to the value of these "quick-tests" when used on alkaline soils where a large portion of the nutrients are in different chemical combination than those in acid soils. For this reason an experiment was designed to determine the agreement between the effects of variations in nutrients as determined by soil analysis and as caused by fertilizer applications.

METHODS

This study was conducted on the Demonstration Farm in the San Luis Valley under sub-irrigation, highly variable soils, and other experimental conditions that have been described in previous papers (2, 3, 5).

A field was divided into two parts, one for soil analysis where no fertilizer additions were made, the other for the addition of fertilizers at known rates and compositions. The first part was further divided into five blocks each containing ten plots. From each of these 50 plots a random soil sample of the top foot of soil was taken and analyzed by the subsequent methods. The other part was also further divided into five blocks each containing ten plots on which fertilizers were applied at planting time by a fertilizer attachment on the potato planter.

Each fertilizer plot and each soil analysis plot was two rows wide and 50 feet long. The fertilizer plots were randomly distributed in each block.

In Part 1 the differences in yield were attributed to the variation in the amount of nutrients already present in the soil as found by soil analysis, whereas in Part 2 the differences in yield which existed after the results were subjected to statistical analysis by the analysis of variance method were attributed to the different amounts and kinds of nutrients added by fertilizer applications. The analyses of a sample taken from the top foot of soil from the soil analysis plots were made by the following methods:

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[1] Scientific Series Paper No. 215, Colorado Agricultural Experiment Station.

Extracting Solution:—The extracting solution was similar to that developed by Brown and Dolberg (1) which has been widely used in alkaline soils. It consisted of 50 grams of sodium acetate and 15 cc of glacial acetic acid per 1000 cc of solution. Twenty cc of this solution was added to 10 grams of air dry soil and after shaking was filtered through a No. 30 Whatman filter paper. The filtrate was used in the subsequent tests.

Each test filtrate was compared with tests of solutions of known concentration (in parts per million) prepared at the same time and in the same manner; thus a direct comparison was possible at the time of reading.

Nitrate:—Three drops of diphenylamine solution were added to one drop of extract; this was allowed to stand for two minutes and then resultant color was read against a series of nitrate standards.

Phosphate:—One drop of 1N H_2SO_4, 1 drop of 1N $NaHSO_3$, and 1 drop of Zinzadze (6) molybdenum blue reagent were used per one cc of extract. Ten cc of this mixture were heated and allowed to simmer until the color developed (five to ten minutes). It was then cooled and the resulting color read against a series of phosphate standards.

Potassium:—Two drops of a sodium-cobalti-nitrite solution and one cc of ethyl alcohol were added dropwise to each cc of extract with constant stirring. A five cc aliquot was used to obtain the color which was read against a series of potassium standards before any precipitate had settled out.

Consideration of Data:—In order to consider the data obtained from the fertilizer plots and the soil analysis plots on a comparable basis, two of the elements added or found to be present were kept constant while the amount of the third element was varied. All differences in yield were then attributed to the variation of the one element. For example, when the yield of potatoes from a plot found to have 4.6 pounds of nitrogen, 1.5 pounds of phosphate, and 96 pounds of potassium per acre-foot of soil was compared to the yield from a plot containing 9.2 pounds of nitrogen, 1.5 pounds of phosphate, and 96 pounds of potassium, the difference in yield between these two plots was attributed to the variation in the amount of nitrate.

Similarly, the difference in yield between a plot which had received fertilizer at the rate of 20 pounds of N, 40 pounds of P_2O_5, and 40 pounds of K_2O per acre and one which had 40 pounds of N, 40 pounds of P_2O_5, and 40 pounds of K_2O applied per acre was considered to be the result of the increased amount of nitrogen added.

In the soil analysis plots the various nutrient levels were compared on the basis of their separate standard deviations while in the fertilizer application plots the various nutrient levels were compared by means of a generalized standard error.

RESULTS

Nitrogen:—In the fertilizer treatments which received neither phosphate nor potassium the addition of nitrogen at the rate of 40 pounds per acre gave a non-significant yield increase of 13 sacks per acre, but in those treatments which received P_2O_5 and K_2O each at the rate of 40 pounds per acre, the addition of nitrogen at the rate of 40 pounds per acre gave a significant yield increase of 87 sacks per acre (Fig. 1).

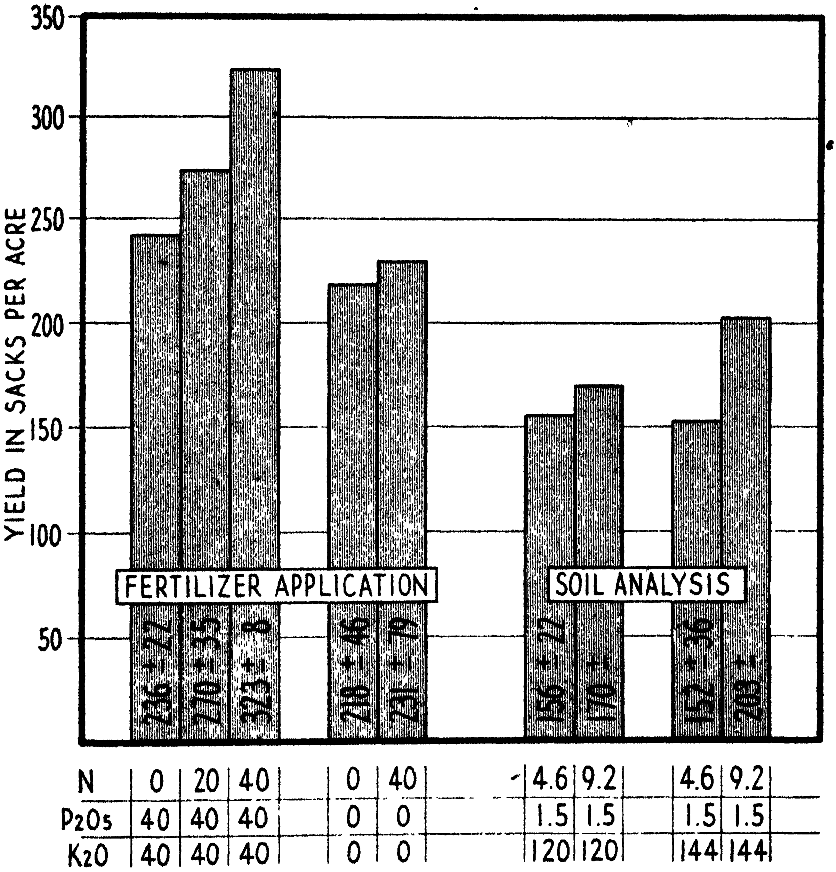

FIG. 1. The effect of varying nitrogen on the yield of Red McClure potatoes.

The soil analysis data showed this same general trend, *i. e.* when the amounts of P_2O_5 and K_2O found in the soil were 1.5 and 96 pounds per acre foot respectively and the amount of nitrogen found changed from 4.6 to 9.2 pounds per acre, the yield increase was only 14 sacks per acre; whereas, when the amounts of P_2O_5 and K_2O found to be present were 1.5 and 120 pounds per acre foot respectively and the amount of nitrogen found changed from 4.6 to 9.2 pounds per acre foot of soil a difference in yield of 51 sacks was noted (Fig. 1).

Phosphate:—In the phosphate fertilizer trials the amount of nitrogen and potassium added remained constant. At one level when neither nitrogen nor potassium was added and the amount of phosphate added changed from zero to 40 pounds per acre the yield increased 23 sacks per acre (Fig. 2). At the other level where nitrogen and potassium were applied at the rate of 10 pounds per acre, an increase from zero to 20 pounds per acre of phosphate gave a yield increase of 32 sacks per acre which is not significant; however, as the amount of phosphate added increased from 20 to 40 pounds per acre a significant yield increase of 102 sacks per acre was obtained (Fig. 2).

The results from the soil analysis plots were similar. When the amounts of nitrogen and potassium were found to be present at a constant rate of 4.6 and 96 pounds per acre foot of soil respectively, the yield was found to increase 15 sacks per acre as the amount of phosphate found varied from 1.5 to 3.0 pounds per acre-foot of soil. With the amount of nitrogen found to be 4.6 pounds per acre-foot of soil and that of potassium found to be 120 pounds per acre-foot, a change in the amount of phosphate found to be present from 1.5 to 3.0 pounds per acre-foot of soil resulted in an increase in yield of 6 sacks per acre, but when the amount of phosphate present in the soil changed to 4.5 pounds per acre-foot the yield increased by 27 sacks per acre (Fig. 2).

A yield increase of 22 sacks per acre was noted when the amount of phosphate found in the soil changed from 1.5 to 3.0 pounds per acre

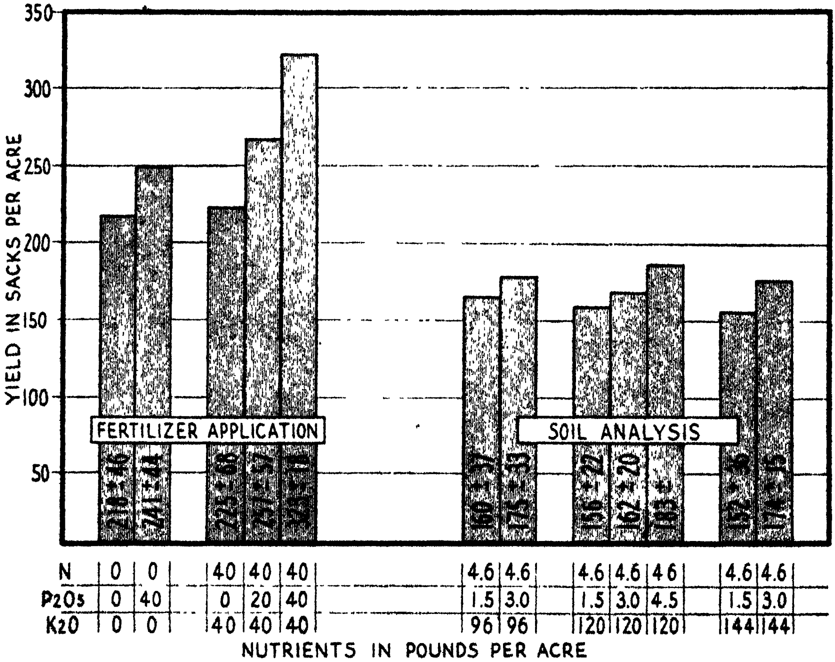

FIG. 2. The effect of varying phosphate on the yield of Red McClure potatoes.

foot of soil and the amounts of nitrogen and potassium found remained constant at 1.5 and 144 pounds per acre foot of soil respectively (Fig. 2).

Potassium:—When no nitrogen or phosphate was added, an increase in the amount of potassium from zero to 40 pounds per acre gave a yield increase of 21 sacks per acre (Fig. 2). When nitrogen and phosphate each were added to the soil at the rate of 40 pounds per acre, an increase in the amount of potassium added from zero to 20 pounds per acre gave a yield increase of 48 sacks per acre, and an increase from zero to 40 pounds per acre gave a significant yield increase of 63 sacks per acre (Fig. 3).

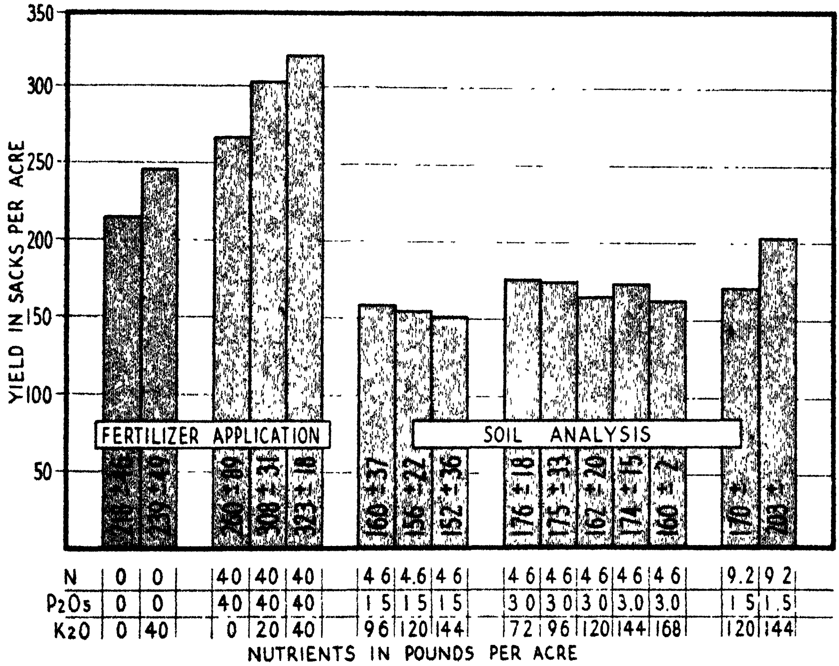

FIG. 3. The effect of varying potassium on the yield of Red McClure potatoes.

The soil analysis plots showed that very little change in yield occurred when the amount of potassium found present in the soil varied from a low to a high level when the nitrogen and phosphate levels were low. When the amounts of nitrogen and phosphate found in the soil were 4.6 and 1.5 pounds per acre-foot respectively, and the amount of potassium found varied from 96 to 120 pounds per acre-foot of soil, a yield decrease of 3 sacks per acre resulted, and when the amount of potassium was found to be 144 pounds per acre-foot of soil a yield decrease of 7 sacks per acre resulted (Fig. 3).

With nitrogen and phosphate found to be present at a constant level of 4.6 and 3.0 pounds per acre foot of soil respectively, a yield decrease of 16 sacks per acre occurred when the amount of potassium found varied from 72 to 168 pounds per acre-foot of soil. A definite change was noted when the amount of nitrogen was found by soil analysis to be 9.2 pounds per acre-foot and the amount of phosphate was found to be 1.5 pounds per acre-foot. In this case as the amount of potassium found changed from 120 to 144 pounds per acre-foot of soil, a yield increase of 33 sacks per acre was obtained (Fig. 3).

Discussion

The data presented indicate that in order to obtain the best results from the addition of nitrogen fertilizers in the San Luis Valley, both phosphate and potassium should also be added. In Fig. 1 a yield increase of 13 sacks per acre is obtained by the addition of nitrogen at the rate of 40 pounds per acre when no phosphate or potassium are added, but a yield increase of 87 sacks per acre is obtained by the addition of 40 pounds per acre of nitrogen when available phosphate and potassium are also added at the rate of 40 pounds per acre. In the soil analysis plots, as the nitrogen content of the soil increased from 4.6 to 9.2 pounds per acre-foot, a yield increase of only 13.6 sacks per acre is obtained when the amounts of phosphate and potassium are 1.5 and 120 pounds per acre-foot, respectively, but with the same nitrogen content an increase of 50.6 sacks per acre is realized when the amounts of phosphate and potassium per acre-foot of soil are 1.5 and 144 pounds respectively. Thus it can be seen that if the supply of phosphate and potassium is adequate, the addition of nitrogen will give an increase in yield which will be great enough to pay for the cost of application, but if the supply of phosphate and potassium is low the addition of nitrogen will not give an increase in yield great enough to pay for the cost of application.

It was found that where no nitrogen or potassium were added the addition of 40 pounds per acre of phosphate to the soil resulted in a yield increase of 23 sacks per acre, but when nitrogen and potassium were added at the rate of 40 pounds per acre each the addition of 40 pounds per acre of phosphate gave a yield increase of 98 sacks per acre (Fig. 2). This again shows the necessity of maintaining the balance between elements.

The yield increase of 23 sacks per acre which was obtained by an addition of 40 pounds per acre phosphate when no nitrogen or potassium was added (Fig. 2), conformed with and added evidence to a series of phosphate fertilizer tests which were run in 1941 (4). The results of this series of tests showed an increase in yield as the amount of phosphate increased to 80 pounds per acre of available phosphate. The soil analysis of Fig. 2 shows this same trend; *i. e.* when nitrogen and potassium were constant at a given amount and the amount of phosphate found to be present in the soil increased, the yield increased.

In the fertilizer trials of Fig. 3, when no nitrogen or phosphate were applied and potassium was applied at the rate of 40 pounds per acre, a yield increase of 21 sacks per acre resulted, but when nitrogen and phosphate were each applied at 40 pounds per acre, a yield increase of 63 sacks per acre resulted from the application of 40 pounds per acre of potassium.

This shows that even though potassium is already present in the soils of this region in high amount (72 to 168 pounds per acre foot of soil extracted by this extracting solution) only very small amounts are available to the plants; thus to maintain the balance between nutrients when nitrogen and phosphate are applied, potassium must also be applied. This is shown also in the soil analysis of Fig. 1, *i. e.*, the soil analyzed N, 4.6 pounds per acre; P_2O_5, 1.5; and K_2O, 120. When 4.6 pounds per acre more nitrogen was found the yield increased only 13 sacks; whereas, when the soil showed an analysis of 9.2 pounds per acre of N, 1.5 pounds per acre of P_2O_5, and 144 pounds per acre of K_2O, the yield increased 44 sacks per acre. This increase was the result not only of the increased amount of nitrogen but also of the additional potassium present. In the soil analysis of Fig. 3 we get the same results but in a different way; as the amount of potassium present in the soil changed from 96 to 144 pounds per acre and the amount of nitrogen and phosphate remained constant at 4.6 and 1.5 pounds per acre-foot of soil respectively, a decrease of 7 sacks per acre was noted. Similarly a decrease of 16 sacks per acre occurred when a soil analyzing 4.6 pounds per acre of N, 3.0 of P_2O_5, and 72 of K_2O was compared to one analyzing 4.6 of N, 3.0 of P_2O_5, and 168 of K_2O. This decrease in yield showed that the nutrients were not in balance, and in order to further show this, compare the soils which analyzed 4.6 pounds per acre of N, 1.5 of P_2O_5, and 144 of K_2O with one which analyzed 9.2 pounds per acre of N, 1.5 of P_2O_5 and 144 of K_2O. It is seen that an increase of 57 sacks per acre resulted in favor of the higher nitrogen. Also compare this same soil to one that analyzed 4.6 pounds per acre of N, 3.0 of P_2O_5 and 144 of K_2O, here a yield increase of 22 sacks per acre is noticed. These increases are not due to an increase in potassium since potassium remains at 144 pounds per acre-foot of soil throughout, but instead these increases are due to the correction of the balance between nitrogen, phosphate, and potassium.

The soils of the San Luis Valley have been tested repeatedly and each time it has been noted that these soils are very high in potassium. Although the conclusions drawn from these soil tests in the past have been that no potassium is needed, the results here imply a need for some additional potassium if nitrogen and phosphate are added (Fig. 3), or even if the amounts of nitrogen and phosphate found present in the soil are high (Figs. 1 and 3). It will be noted that, as the amount of potassium increases when no nitrogen or phosphate are added, the yield decreased (Fig. 3), but it should also be noted in contrast to this that when there was an adequate supply of nitrogen and phosphate added, the addition of potassium gave a yield increase of 63 sacks per acre. This same condition is found in Fig. 3 in connection with the soil analysis curves. Here again is evidence that a complete fertilizer gave better results than did the addition of a single element.

SUMMARY

As has already been pointed out in the previous discussion there is a close relationship between the results from the fertilizer application trials and the soil analysis plots. The comparisons of these graphs (Figs. 1, 2 and 3) indicate that the "quick-test" method used for testing the alkaline San Luis Valley soils are of value, provided the results of the tests are interpreted so that each element is not only a function of the element tested but is a function of the other elements as well.

In order to get the true relationship between the elements the basis for judgment should be plant response rather than chemical tests showing the parts per million of the elements which are extracted by some acid extracting solution. When an acid extracting agent is used, in all probability there is more phosphate and potassium extracted than can be extracted by the plant itself; thus the using of the amounts of these elements extracted by an acid extracting solution as an indication of the fertility of the soil leads to difficulty. But if the soil tests are used to supplement plant response data, then it is possible that a fertilizer balance or ratio can be worked out for given fields on the basis of soil analysis.

The following points show that each element is a function of not only the amount of that element present but of the others present also:

With the phosphate and potash levels high, an increase in yield occurred when nitrogen was increased from 0 to 40 pounds per acre. Similar results were obtained by soil analysis.

In both the soil analysis plots and fertilizer trials all levels of nitrogen and potassium gave an increase in yield when phosphate was increased.

With the nitrogen and phosphate levels high, an increase in yield occurred when the amount of potassium applied was increased from zero to 40 pounds per acre.

A complete fertilizer gave better yields than was obtained by the addition of any single element alone, or any two elements without the third element being present.

CONCLUSION

The "quick-test" method of soil analysis used herein is of value if results are interpreted correctly. Using plant response as the basis for interpretation of results, a very close relationship was found to exist between the results obtained by soil analysis and those obtained when fertilizers were applied to the soil. This is true in the case of each of the three elements.

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Aerosol Applications of Growth Regulating Substances to the Greenhouse Tomato

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Up to the present the only method of applying growth-regulating substances to commercially grown greenhouse tomatoes is their tedious and time consuming application, by means of small atomizers, to each individual flower, at the base of the stamens. Obviously some more efficient system of application is highly desirable.

The utilization of the so-called aerosol "bomb", as first suggested for this purpose by Hamner, Schomer, and Goodhue (1) would seem to offer promise. The "bomb" is a metal cylinder which holds the liquified gas and releases it by means of a suitable nozzle to produce a mist or fog of aerosol. Later work (2) indicated that mature seedless or partially seedless fruits could be produced as a result of this type of treatment. It remained, however, to determine the relative proportion of treated flowers which develop into fruits, and their size and pulp development. Zimmerman and Hitchcock (3) presented results showing that application directly to the cluster, as opposed to the individual flowers, resulted in 85 per cent set as compared with the complete failure of fruit development from the non-pollinated control flowers. Data were not given, however, as to the effect of this type of application upon fruit size and quality, factors which in the last analysis are the determining ones in the whole problem of commercial treatment. It is the purpose of this paper to present the results of aerosol application upon fruit set, size, and pulp development of greenhouse tomatoes.

During the spring-crop season of 1945, in two greenhouses in the vicinity of Cleveland, Ohio, the individual atomizer application of growth-regulating substances, both in water solution and in emulsion, was compared with aerosol application of the same chemicals. The aerosol treatments involved the following chemicals at the concentrations listed:

1. Indolebutyric acid (IB) .025 per cent
2. Beta-naphthoxyacetic acid (BNOA) .025 per cent
3. Indolebutyric acid (IB) .0125 per cent and beta-naphthoxyacetic acid (BNOA) .0125 per cent
4. Indolebutyric acid (IB) .0125 per cent, beta-naphthoxyacetic acid (BNOA) .0125 per cent and 4—chlorophenoxyacetic acid (4 Cl) .001 per cent
5. Aerosol control-cyclohexanone

The growth-regulating substances had been placed in the cylinders in 5 per cent cyclohexanone and 94.975 per cent dimethyl ether. The aerosol application was directed to each cluster with particular care not to strike the stem. One greenhouse was located in the range owned by the Ohio Greenhouse Company, Rocky River; the other belonged to the Olmsted Greenhouse Company, Olmsted Falls. Each house contained at least 1600 plants all of which were under test. In the Ohio Greenhouse Company 12 treatments comprising 156 plants each and in the Olmsted Greenhouse Company 20 treatments of 82 plants each, were replicated three times and established at random with certain restrictions.

The period of treatment began February 13 and continued until three clusters had been treated (March 16). The solutions and emulsions were applied every fifth day, each cluster receiving approximately three applications. On the other hand, the aerosol treatments were applied either once or three times to a cluster. The flower clusters on both the treated and untreated plants were shaken or tapped to effect pollination, since these treatments were not necessarily designed to produce seedless fruits but to supplement pollination and fertilization.

The fruit developing per cluster were recorded for the three treated clusters and for the three succeeding untreated clusters. Records were kept of the fruit ripening on all six clusters until the end of May, at which time all the fruits on the three treated clusters had ripened. Fruits were counted and weighed and at intervals cut and examined. At the same time the fruits on the three succeeding untreated clusters which had ripened up to that time were also counted and weighed.

PRESENTATION OF RESULTS

The cumulative weekly increase in total weight of fruits per plant for the treatments showing the five highest yields (See Table I) are presented graphically in Fig. 1. Comparison of the graphs for these and the untreated plants shows not only a preponderant increase in early fruit production but also an outstanding difference at the end of the period between the treated and untreated plants.

Fig. 1 shows that the three chemicals, indolebutyric acid, beta-naphthoxyacetic acid and 4–chlorophenoxyacetic acid when applied by the aerosol method both once or three times to a cluster, ranked highest. The aerosol treatment with beta-naphthoxyacetic acid alone, and the standard lanolin emulsion containing both indolebutyric acid (0.2 per cent) and beta-naphthoxyacetic acid (50 ppm) gave practically the same increases over the untreated plants. The aerosol treatments with mixture of indolebutyric acid and beta-naphthoxyacetic acid and that with indolebutyric acid alone were next in order. The repeated application of each material showed a slight increase over the single application per cluster.

The calculated total weight of fruits harvested from the fourth to sixth clusters is also presented in Table I. The average number of fruits per cluster (see Table II) and the average weight of the fruits harvested up to the end of May were used in calculating the total weight of fruits presumably harvested in entirety from the three untreated clusters. Obviously an element of error is involved in such a calculation but presumably it gives a fairly close estimate of the true yield. The data indicate considerable difference in the yield of these three succeeding untreated clusters. Plants subjected to the four treatments producing the highest yields in the first three clusters showed

TABLE I—WEIGHT OF TOMATO FRUITS PER PLANT ON TREATED AND UNTREATED CLUSTERS AT OHIO GREENHOUSE COMPANY (HOUSE 3). SPRING CROP, 1945. CLUSTERS 1 TO 3 TREATED, EXCEPT CHECK: CLUSTERS 4–6 UNTREATED

Treatment*	Total Weight Treated Fruits (Ounces)	Gain Over Untreated (Ounces)	Calculated Total Weight of Fruits From Untreated Clusters (Ounces)			Total** Weight 6 Clusters (Ounces)	Gain Treated** Over Plants Untreated (Ounces)
			Cluster 4	Clusters 5-6	Total 4-6		Clusters 1-6
Aerosol-IB, BNOA, 4-Cl-1 application	58.7	40.1	10.5	36.8	47.3	106.0	33.9
Same—3 applications. . . .	52.7	34.1	8.8	34.4	43.2	95.9	23.8
Aerosol—BNOA—3 applications.	46.2	27.6	7.7	32.4	40.1	86.3	14.2
.2 IB, BNOA 50 ppm emulsion†	46.1	27.5	8.2	34.8	43.0	89.1	17.0
Aerosol—BNOA—1 application	45 0	26.4	9.8	46.9	56.7	101.7	29 6
Aerosol-IB, BNOA-3 applications.	40.6	22.0	8.7	40.8	49.5	90.1	18.0
.2 IB emulsion†	37.2	18.6	12.0	45.2	57.2	94.4	22.3
Aerosol-IB, BNOA-1 application.	35.3	16 7	9.8	36.8	46.6	81.9	9.8
Aerosol-IB-1 application	31.6	13 0	13 2	44.6	57.8	89 4	17.3
Same—3 applications. . . .	30.3	11.7	9.2	38.2	47.4	77.7	5.6
Aerosol control.	26.2	7.6	11.9	41 3	53 2	79.2	7.3
Untreated	18.6	——	10.8	42.7	53.5	72.1	——

*The meaning of the symbols given above is as follows:
IB = Indolebutyric acid.
BNOA = Beta-naphthoxyacetic acid.
4-Cl = 4-Chlorophenoxyacetic acid.
Ppm = parts per million.
**Based in part on calculated total yield, column 6.
†Emulsion contains 4 grams lanolin in 300 ml. volume.

less total weight in the fourth to sixth clusters than did the untreated plants. Certain treatments that gave increased weight in the first three clusters might have been expected to show a decrease in production in the next three, but, nevertheless, produced quite as much fruit as the untreated checks.

Undue emphasis should not be placed upon the gain of a particular treatment as opposed to the untreated since the value of any given treatment must depend in large part directly upon the size and quality of the fruits produced in response to treatment. For example, the aerosol treatment with indolebutyric acid alone produced small, rough, inferior fruits on the first three clusters. Likewise, the aerosol treatment consisting of one application of beta-naphthoxyacetic acid produced fruits that were quite hollow and variable in size. Indolebutyric acid (0.2 per cent) in lanolin emulsion also produced fruits that were, in general, too small (although larger than the untreated), but its final over-all gain was 22 calculated ounces per plant. None of these three treatments were as desirable commercially as those that showed the greatest earlier yield.

Table II presents the average number of fruits set on each of the six clusters in this house. It is to be noted that all treated plants showed an increase in the number of fruits developing in the first three clusters when compared with the check. The actual total increase in number of fruits resulting from the best treatments ranged from

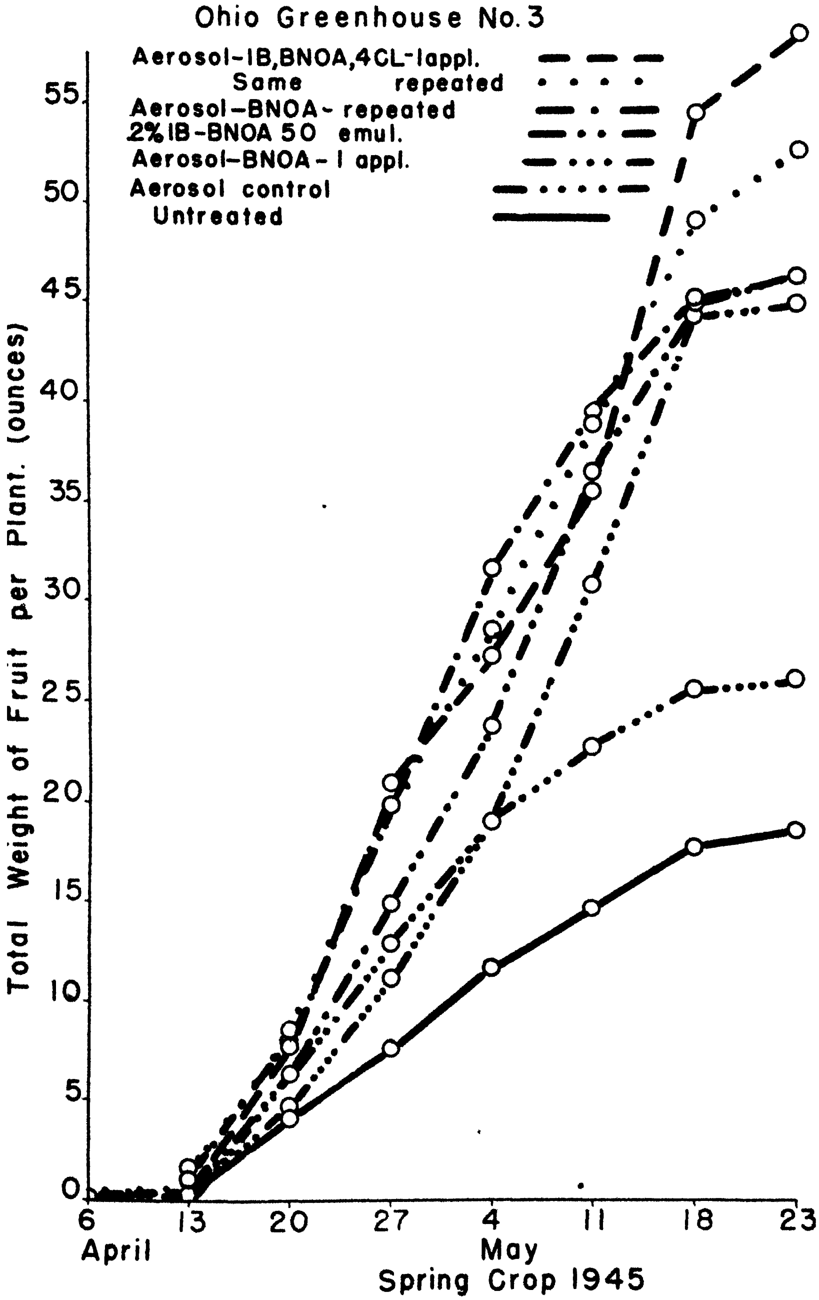

FIG. 1. Ohio Greenhouse Company. Cumulative increase in total weight (ounces) of tomato fruits per plant for five highest-yielding treatments (and the untreated plants). First three clusters. Spring crop, 1945.

TABLE II—AVERAGE NUMBER OF TOMATO FRUITS PER CLUSTER ON TREATED AND UNTREATED PLANTS. OHIO GREENHOUSE COMPANY (HOUSE 3). SPRING CROP, 1945. CLUSTERS 1 TO 3 TREATED, EXCEPT CHECK: CLUSTERS 4–6 UNTREATED

Treatment*	Treated Clusters				Untreated Clusters			
	Cluster 1	Cluster 2	Cluster 3	Total Clusters 1-3	Cluster 4	Clusters 5-6	Total Clusters 4-6	Total Clusters 1-6
Aerosol–IB, BNOA, 4-Cl-1 application	2.9	2.4	3.6	8.9	2.4	7.3	9.7	18.6
Same—3 applications	2.8	2.6	2.8	8.2	2.1	5.7	7.8	16.0
Aerosol–BNOA–3 applications	2.5	2.7	2.1	7.3	2.0	6.3	8.3	15.6
.2 IB, BNOA 50 ppm emulsion	2.4	3.0	2.9	8.3	1.9	6.1	8.0	16.3
Aerosol–BNOA–1 application	2.4	2.6	2.9	7.9	2.5	8.3	10.8	18.7
Aerosol–IB, BNOA–3 applitions	2.8	3 1	1.8	7.7	2.0	6.9	8.9	16.6
.2 IB emulsion	2.6	2.6	2.8	8.0	2.8	7.9	10.7	18.7
Aerosol–IB, BNOA–1 application	2.5	2.8	1.6	6.9	2 3	6.6	8.9	15.8
Aerosol–IB–1 application	2.7	3.0	2.1	7.8	2.9	7.9	10.8	18.6
Same—3 applications	1.8	2.7	2.8	7.3	2 2	7 6	9.8	17.1
Aerosol control	2.3	2.7	1.9	6.9	3 0	8 0	11.0	17.9
Untreated	1.8	1.9	1.5	5.2	2.6	7.5	10.1	15.3

*See Table I.

40 to 70 per cent. On an individual cluster basis (first 3 clusters) the number of fruits in certain treatments was nearly double that from the untreated plants. The aerosol treatment involving a mixture of the three chemicals applied once to a cluster was superior to all other treatments in this respect. The standard emulsion applied individually to the flowers, and the aerosol treatment containing the three chemicals in repeated application was next best.

The data for the three succeeding clusters show some compensation in fruit development in the case of certain treatments, but not in others, in comparison with the same clusters on untreated plants. Actually, in certain instances, more fruits were produced on these three succeeding clusters than on comparable clusters of the untreated plants. This result occurred with the lanolin emulsion containing indolebutyric acid, with the aerosol treatments with the same chemical, and with beta-naphthoxyacetic acid alone (one application). This was not the case, however, with the highest-yielding treatments in which there was a definite reduction in fruits in the three succeeding untreated clusters. Furthermore, despite this partial compensation the treated plants showed a greater total number of fruits than the untreated.

Table III, presenting the average weight of a single fruit on both the treated and untreated plants, shows that the highest-yielding treatments were characterized by the largest fruits. In fact, with the exception of one aerosol treatment (indolebutyric acid and beta-naphthoxyacetic acid applied once), the decreasing yield is accompanied by a decrease in size. It is to be noted that the superior treatments produced an increase over the untreated ranging from 52 to 64 per cent. The average size attained by the fruits (Table III) fails to give a true picture, since it indicates little of the variations in quality which

TABLE III—AVERAGE WEIGHT OF SINGLE TOMATO FRUITS ON TREATED AND UNTREATED CLUSTERS. OHIO GREENHOUSE COMPANY (HOUSE 3). CLUSTERS 1 TO 3. SPRING CROP, 1945

Treatment*	Average Weight Single Fruit (Ounces)	Comparative Percentage Values (Untreated = 100)
Aerosol-IB, BNOA, 4-Cl-1 application	6.7	160
Same—3 applications	6.9	164
Aerosol-BNOA-3 applications	6.7	160
.2 IB, BNOA 50 ppm emulsion	6.4	152
Aerosol-BNOA-1 application	6.1	145
Aerosol-IB, BNOA-3 applications	5.7	136
.2 IB emulsion	5.2	124
Aerosol-IB, BNOA-1 application	6.7	160
Aerosol-IB, 1 application	4.3	102
Same—3 applications	4.5	107
Aerosol control	4.2	100
Untreated	4.2	100

*See Table I.

occurred in certain treatments. For example, fruits from the three untreated clusters of the untreated plants were, at first, invariably small, wrinkled, and rough, a condition due largely to inadequate pollination and fertilization. As the season advanced into May the fruits increased in average size and their appearance improved although they were still unsatisfactory. The fruits treated with aerosol containing indolebutyric acid showed little improvement over the untreated until the later pickings. Furthermore, the single aerosol application produced fruits more variable in size than those obtained by repeated applications.

Table IV presents results from examining the cut fruits. Seventy-six per cent of the untreated fruits showed no hollowness in the seed-containing cavities and in this respect no treated fruits showed improvement over the untreated in this house. Fruits treated with indolebutyric acid emulsion showed about the same percentage of well-filled as the untreated, but the fruits resulting from the standard emul-

TABLE IV—PROPORTION OF HOLLOW LOCULES AND COLOR OF GELATINOUS PULP IN TREATED AND UNTREATED FRUITS. OHIO GREENHOUSE COMPANY (HOUSE 4). CLUSTERS 1 TO 3. SPRING CROP, 1945

Treatment*	Percentage Distribution Among Fruits Examined					
	Hollowness of Locules			Color of Pulp		
	Well Filled	Some Pulp	Poorly Filled	Completely Red	Partly Green	Green
Aerosol-IB, BNOA, 4-Cl-1 application	56.0	—	44.0	80.0	12.0	8.0
Same—3 applications	44.0	4.0	52.0	80.0	16.0	4.0
Aerosol-BNOA-3 applications	28.0	4.0	68.0	88.0	8.0	4.0
.2 IB, BNOA 50 ppm emulsion	60.0	—	40.0	72.0	24.0	4.0
Aerosol-BNOA-1 application	40.0	8.0	52.0	88.0	12.0	—
Aerosol-IB, BNOA-3 applications	76.2	—	23.8	76.2	23.8	—
.2 IB emulsion	72.0	—	28.0	44.0	40.0	16.0
Aerosol-IB, BNOA-1 application	76.5	—	23.5	58.8	17.7	23.5
Aerosol-IB-1 application	76.5	5.9	17.6	100.0	—	—
Same—3 applications	61.9	4.8	33.3	95.2	4.8	—
Aerosol control	58.8	11.8	29.4	100.0	—	—
Untreated	76.0	4.0	20.0	96.0	4.0	—

*See Table I.

sion containing beta-naphthoxyacetic acid in addition to indolebutyric showed some fruits whose seed cavities were slightly hollow. Fruits treated with aerosols alone, on the other hand, were distinctly hollow; the cavities, when examined, being only partially filled. Even before cutting the fruits often seemed hollow, were distinctly ribbed, and quite generally inflated. In addition, the aerosol treatments containing the three growth-regulating substances together, beta-naphthoxyacetic acid alone, and both indolebutyric and beta-naphthoxyacetic acids produced particularly poor results. Repeated applications were undoubtedly superior to the single treatment with respect to smoothness, uniformity of size and general appearance of the fruit. Insofar as this house was concerned atomizer application of the standard emulsion containing indolebutyric and beta-naphthoxyacetic acids was distinctly superior to any aerosol application in this respect.

On the other hand, the color of the pulp in the aerosol-treated fruits was undoubtedly superior. In a much greater proportion the gelatinous pulp was completely red, rather than tinged with the green as was characteristic of many of the fruits produced by the emulsions containing indolebutyric acid. The emulsion of indolebutyric acid alone showed only 44 per cent of the fruits to be free of any green tinge although the standard emulsion showed some improvement over this percentage.

Tables V to VIII present the results of various treatments in the Olmsted Greenhouse Company. In this greenhouse only half the treatments were concerned with the aerosol method. It should be emphasized at this point that the conditions in the two houses were quite different as to air temperature and humidity, a fact which accounts in part for conflicting results. At Olmsted both the night and day temperatures were distinctly higher than at the Ohio Greenhouse Company, thus producing a condition more favorable to natural fruit set.

Fig. 2 presents the cumulative weekly increase in total weight of fruits per plant for the five most successful treatments. The graphs comparing these with the untreated plants show a preponderant increase in early fruit production. Fig. 2 also shows a pronounced difference in total yields between the treated and untreated plants, a difference which, however, was not so great as that obtained at the Ohio Greenhouse Company.

Table V shows that the total yield of fruits produced by indolebutyric acid (.2 per cent) and beta-naphthoxyacetic acid (50 ppm) was superior to all other treatments, but by a narrow margin only, as compared with the lanolin emulsion of the same chemicals at half the concentration. The next best treatments were nearly alike in their productive capacity. Results were similar with the standard emulsion of indolebutyric and beta-naphthoxyacetic acids, beta-naphthoxyacetic acid in water solution (50 ppm), the aerosol treatment composed of the three chemicals, and the aerosol containing beta-naphthoxyacetic acid alone, applied repeatedly.

Results from all the aerosol treatments were, however, quite similar in some respects to those found in the tests at the Ohio Greenhouse

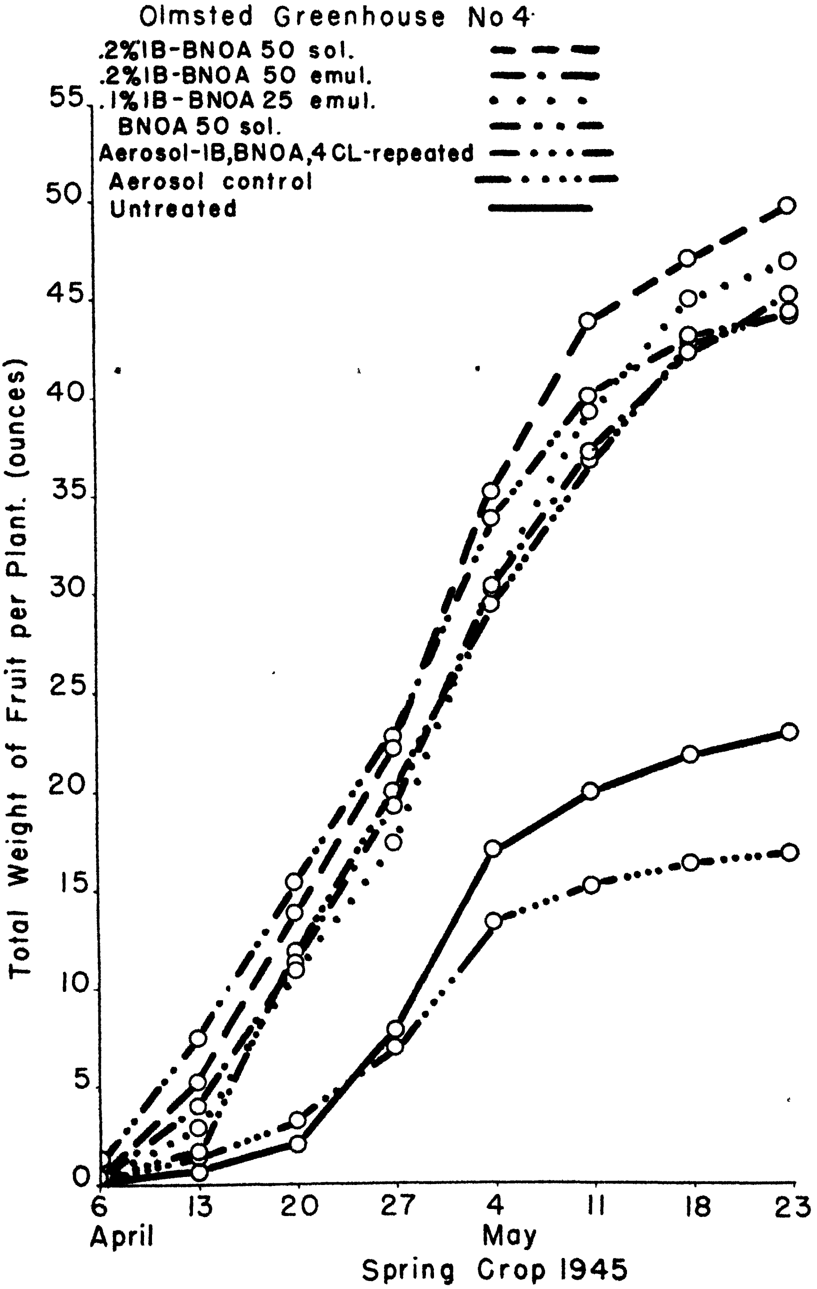

FIG. 2. Olmsted Greenhouse Company. Cumulative increase in total weight (ounces) of tomato fruits per plant for five highest yielding treatments (and the untreated plants). First three clusters. Spring crop, 1945.

TABLE V—WEIGHT OF TOMATO FRUITS PER PLANT ON TREATED AND UNTREATED CLUSTERS. OLMSTED GREENHOUSE COMPANY (HOUSE 4). SPRING CROP, 1945. CLUSTERS 1 TO 3 TREATED, EXCEPT CHECK: CLUSTERS 4–6 UNTREATED

Treatment*	Total Weight Treated Fruits (Ounces)	Gain Over Untreated (Ounces)	Calculated Total Weight of Fruits From Untreated Clusters (Ounces)			Total‡ Weight 6 Clusters (Ounces)	Gain Treated‡ Over Plants Untreated (Ounces)
			Cluster 4	Clusters 5–6	Total 4–6		Clusters 1–6
.2 IB, BNOA 50 ppm solution	49.8	26.9	6.7	29.8	36.5	86.3	15.4
.1 IB, BNOA 25 ppm emulsion	47.0	24.1	9.7	34.9	44.6	91.6	20.7
.2 IB, BNOA 50 ppm emulsion	45.2	22.3	9.4	24.3	33.7	78.9	8.0
BNOA 50 ppm solution	44.4	21.5	6.1	27.5	33.6	78.0	7.1
Aerosol-IB, BNOA, 4-Cl-3 applications	44.1	21.2	7.5	21.6	29.1	73.2	2.3
Aerosol–BNOA–3 applications	43.9	21.0	9.2	29.8	39.0	82.9	12.0
BNOA 25 ppm solution	42.3	19.4	7.6	23.0	30.6	72.9	2.0
.2 IB, BNOA 25 ppm emulsion	39.0	16.1	6.6	26.9	33.5	72.5	1.6
Aerosol–IB, BNOA, 4-Cl-1 application	38.0	15.1	9.6	33.0	42.6	80.6	9.7
.2 IB–107 emulsion**	37.9	15.0	13.0	37.9	50.9	88.8	17.9
Aerosol–BNOA–1 application	37.2	14.3	10.3	29.1	39.4	76.6	5.7
.2 IB emulsion	36.5	13.6	9.4	34.7	44.1	80.6	9.7
Aerosol–IB, BNOA–1 application	31.9	9.0	10.3	30.1	40.4	72.3	1.4
.2 IB+orvus paste solution	31.3	8.4	10.0	35.1	45.1	76.4	5.5
Aerosol–IB, BNOA–1 application	27.1	4.2	13.8	34.5	48.3	75.4	4.5
.2 IB–105 A emulsion†	26.9	4.0	12.6	39.2	51.8	78.7	7.8
Untreated	22.9	—	11.5	36.5	48.0	70.9	—
Aerosol–IB–3 applications	20.7	–2.2	13.5	37.4	50.9	71.6	0.7
Same—1 application	18.1	–4.8	13.5	37.8	51.3	69.4	–2.2
Aerosol control	16.9	–6.0	11.4	40.7	52.1	69.0	–1.9

*See Table I.
**Carnauba wax, lanolin, cetyl alcohol, and Pharmagel B utilized in making emulsion.
†Carnauba wax and Pharmagel B utilized in place of lanolin.
‡Based in part on calculated total yield, column 6.

Company. In each instance repeated applications proved superior to the single application per cluster. The aerosol treatment with indolebutyric acid alone was practically useless and only a small improvement was produced by adding beta-naphthoxyacetic acid to indolebutyric. The aerosol control actually resulted in this case in a slight reduction in set.

The calculated total weight of fruits harvested from the fourth to sixth clusters indicates considerable difference between treatments in the yield of these three untreated clusters, although, in general, all treatments that showed distinct improvement in the first three clusters, showed less total weight in the fourth to the sixth than was the case with the untreated plants. Indolebutyric acid emulsion 107 was the exception. The emulsion of indolebutyric acid (.1 per cent) and beta-naphthoxyacetic acid (25 ppm) produced nearly as much weight as the untreated plants. On the basis of calculated total yield only four treatments showed outstanding improvement over the untreated plants. Since some error is undoubtedly inherent in these yields, projected for six clusters, undue emphasis should not be placed upon the apparent superiority of these treatments. Furthermore, indolebutyric acid emulsion 107 has no practical significance since the fruits resulting from treatment (first three clusters) were small, rough, wrinkled, and largely undesirable.

Table VI presents the average number of fruits set on each of the first six clusters. The three highest-yielding treatments and indolebutyric acid emulsion 107 produced the greatest total number of fruits on the treated clusters. The extent of this increase over the untreated ranged from 37 to 53 per cent. Except for these treatments there was no particular relationship between the total number of fruits on the first three clusters and the total yield or weight, thus indicating the extent to which fruit size rather than number determined the degree to which treatment proved successful.

TABLE VI—AVERAGE NUMBER OF TOMATO FRUITS PER CLUSTER ON TREATED AND UNTREATED PLANTS. OLMSTED GREENHOUSE COMPANY (HOUSE 4). SPRING CROP, 1945. CLUSTERS 1 TO 3 TREATED, EXCEPT CHECK. CLUSTERS 4–6 UNTREATED

Treatment*	Treated Clusters				Untreated Clusters			
	Cluster 1	Cluster 2	Cluster 3	Total Clusters 1–3	Cluster 4	Clusters 5–6	Total Clusters 4–6	Total Clusters 1–6
.2 IB, BNOA 50 ppm solution	3.1	3.7	3.2	10.0	1.8	5.3	7.1	17.1
.1 IB, BNOA 25 ppm emulsion	3.3	3.6	3.5	10.4	2.3	6.3	8.6	19.0
.2 IB, BNOA 50 ppm emulsion	2.9	3.5	2.9	9.3	2.2	5.8	8.0	17.3
BNOA 50 ppm solution	2.8	3.0	2.5	8.3	1.3	5.6	6.9	15.2
Aerosol-IB, BNOA, 4-Cl-3 application	3.1	3.0	2.4	8.5	1.9	5.4	7.3	15.8
Aerosol-BNOA—3 applications	2.4	2.7	3.0	8.1	2.2	6.5	8.7	16.8
BNOA 25 ppm solution	3.2	2.7	2.6	8.5	2.0	6.0	8.0	16.5
.2 IB, BNOA 25 ppm emulsion	2.9	3.2	2.5	8.6	1.7	5.6	7.3	15.9
Aerosol-IB, BNOA, 4-Cl-1 application	2.5	2.3	2.7	7.5	2.2	6.9	9.1	16.6
.2 IB–107 emulsion	3.2	3.9	3.2	10.3	2.8	0.9	9.7	20.0
Aerosol-BNOA—1 application	2.5	2.1	2.6	7.2	2.6	6.5	9.1	16.3
.2 IB emulsion	2.7	3.8	2.9	8.9	2.1	6.6	8.7	17.6
Aerosol-IB, BNOA—3 applications	2.1	2.9	2.5	7.5	2.3	6.5	8.8	16.3
.2 IB +orvus paste solution	2.2	3.4	3.2	8.8	2.6	7.7	10.3	19.1
Aerosol-IB, BNOA-1 application	1.8	2.5	2.8	7.1	3.1	7.6	10.7	17.8
.2 IB–105 A emulsion	2.2	3.2	2.8	8.2	3.2	8.3	11.5	19.7
Untreated	1.3	2.9	2.6	6.8	2.7	7.3	10.0	16.8
Aerosol-IB-3 applications	1.6	2.6	2.9	7.1	3.4	8.0	11.4	18.5
Same—1 application	1.4	2.4	2.9	6.7	3.1	7.9	11.0	17.7
Aerosol control	1.3	2.1	2.6	6.0	2.7	8.4	11.1	17.1

*See Table I.

Examination of the data for the three succeeding clusters presents some interesting results. Treatments that on the first three clusters gave no more than 9 ounces increase in yield over the untreated, showed as many fruits developing on the last three clusters as on the untreated plants. In every case the higher-yielding treatments showed fewer fruits developing on the later clusters than were developed on the untreated plants. Furthermore, the relationship between treatments was not consistent. For example, the aerosol treatment involving beta-naphthoxyacetic acid alone produced as many fruits on the fourth to sixth clusters as indolebutyric acid emulsion which on the first three clusters had produced 50 per cent less fruit than the other and thus might normally be expected to show later compensatory effects. Finally, only the three most productive treatments showed more fruits for six clusters than did the untreated plants. Even here, with the exception of one treatment, the margin was small. However, as previously indicated, the number of fruits is not the sole criterion for judging the value and efficacy of treatment. The fruits on the first three clusters of the untreated plants were inferior in nearly every respect to the early fruits produced by the higher-yielding treatments whether solutions, emulsions, or aerosol applications.

Table VII presents the average weight of a single fruit taken from the first three clusters of both the treated and untreated plants. Although, in general, the treatments in which the yields were highest produced the largest fruits a few exceptions were evident. These exceptions consisted of cases in which the number of fruits developing was particularly large. For example, while the emulsion containing indolebutyric acid (.1 per cent) and beta-naphthoxyacetic acid (25 ppm) showed an increase of only 34 per cent in size yet it ranked second in yield. It showed, however, the greatest gain of any treatment in number of fruits on the three treated clusters. Another example was the aerosol application of beta-naphthoxyacetic acid applied once to a cluster. It produced particularly large fruits but the number as compared with the untreated was relatively small. It should also be noted that the fruits produced by the water solutions of indolebutyric acid and of beta-naphthoxyacetic acid were nearly as large as those

TABLE VII—AVERAGE WEIGHT OF SINGLE TOMATO FRUITS FROM TREATED AND UNTREATED PLANTS OLMSTED GREENHOUSE COMPANY (HOUSE 4). CLUSTERS 1 TO 3 SPRING CROP, 1945

Treatment*	Average Weight Single Fruit (Ounces)	Comparative Percentage Values (Untreated = 100)
.2 IB, BNOA 50 ppm solution	5.8	153
.1 IB, BNOA 25 ppm emulsion	5.1	134
.2 IB, BNOA 50 ppm emulsion	6.1	161
BNOA 50 ppm solution	5.8	153
Aerosol–IB, BNOA, 4-Cl-3 applications	6.3	166
Aerosol- BNOA 3 applications	6.4	168
BNOA 25 ppm solution	6.1	161
.2 IB, BNOA 25 ppm emulsion	5.5	145
Aerosol–IB, BNOA, 4-Cl-1 application	5.7	150
.2 IB–107 emulsion	4.4	116
Aerosol–BNOA-1 application	6.0	158
.2 IB emulsion	4.9	129
Aerosol–IB, BNOA 3 applications	4.9	129
.2 IB + orvus paste solution	4.5	118
Aerosol–IB, BNOA-1 application	4.6	121
.2 IB–105 A emulsion	3.9	103
Untreated	3.8	100
Aerosol–IB–3 applications	3.8	100
Same—1 application	3.3	87
Aerosol control	3.3	87

*See Table I.

produced by the lanolin emulsions of the same chemicals at the same concentration.

Table VIII presents data from the Olmsted Greenhouse Company relative to internal development, or the degree to which fruits showed no hollowness. The outstanding fact to be noted is the very satisfactory pulp development that was maintained with all treatments, particularly the aerosols. This result was in distinct contrast to the situation at the Ohio Greenhouse Company. Comparison of Table IV with Table VIII indicates the superiority of even the untreated fruits at Olmsted over the untreated at Ohio. The aerosol treatment consisting of the three chemicals at repeated applications, while slightly inferior to the other treatments, was, nevertheless, reasonably satisfactory.

TABLE VIII—PROPORTION OF HOLLOW LOCULES AND COLOR OF GELATINOUS PULP IN TREATED AND UNTREATED FRUITS. OLMSTED GREENHOUSE COMPANY (HOUSE 4). CLUSTERS 1 TO 3. SPRING CROP, 1945

Treatment*	Percentage Distribution Among Fruits Examined					
	Hollowness of Locules			Color of Pulp		
	Well Filled	Some Pulp	Poorly Filled	Completely Red	Partly Green	Green
.2 IB, BNOA 50 ppm solution	82.3	5.9	11.8	29.4	41.2	29.4
.1 IB, BNOA 25 ppm emulsion	100.0	—	—	23.3	33.8	42.9
.2 IB, BNOA 50 ppm emulsion	88.2	—	11.8	35.3	34.3	29.4
BNOA 50 ppm solution	94.1	—	5.9	64.7	17.7	17.6
Aerosol-IB, BNOA, 4-Cl-3 applications	76.5	—	23.5	41.2	41.2	17.6
Aerosol-BNOA 3 applications	82.3	5.9	11.8	17.6	46.1	35.3
BNOA 25 ppm solution	88.2	—	11.8	29.4	35.3	35.3
.2 IB, BNOA 25 ppm emulsion	92.8	—	7.2	21.4	28.6	50.0
Aerosol IB, BNOA, 4-Cl-1 application	64.7	5.9	29.4	70.6	23.5	5.9
.2 IB 107 emulsion	100.0	—	—	52.9	23.6	23.5
Aerosol BNOA-1 application	87.6	6.2	6.2	25.0	56.2	18.8
.2 IB emulsion	94.1	—	5.9	29.4	23.5	47.1
Aerosol IB, BNOA-3 applications	82.4	—	17.6	58.8	17.7	23.5
.2 IB +orvus paste solution	94.1	—	5.9	29.4	29.4	41.2
Aerosol-IB, BNOA-1 application	94.1	—	5.9	70.6	23.5	5.9
.2 IB-105 A emulsion	96.0	—	4.0	44.0	16.0	40.0
Untreated	94.1	—	5.9	82.4	11.7	5.9
Aerosol-IB 3 applications	92.9	—	7.1	78.6	7.1	14.3
Same 1 application	100.0	—	—	77.1	17.0	5.9
Aerosol control	88.2	—	11.8	100.0	—	—

*See Table I.

Even the solution and emulsion produced slightly more hollowness than was the case with the untreated fruits, which, while small and somewhat wrinkled, exhibited little hollowness. Moreover, it was quite surprising to find that the solution of beta-naphthoxyacetic acid (50 ppm) resulted in such internally satisfactory fruits, since this was contrary to the writers' experience up to this point.

On the other hand, all the higher-yielding treatments resulted in less red pulp color than was found in the untreated, although these too showed a slightly greenish tinge, which in either case was not sufficient to make the fruits commercially undesirable. Beta-naphthoxyacetic acid solution was superior in this respect to all the higher-yielding treatments, although when applied by the aerosol method it was at the bottom of the list — a direct contrast to the results at the Ohio Greenhouse Company.

DISCUSSION

The results presented in this paper are concerned with the effect upon tomato fruit set and development of certain growth-regulating substances (primarily indolebutyric and beta-naphthoxyacetic acids) when applied, either together or singly, in solutions, emulsions, or as an aerosol mist. Particular attention is given in this discussion to the aerosol method of application which is much more convenient and less time-consuming than the treatment of the individual flower by means of atomizers. These tests were conducted in two greenhouses in the Cleveland, Ohio, area in which the growing conditions, with particular reference to air temperature and humidity, were significantly different. Although differences in the nature of the fruit produced in these two houses might have been predicted, the extent to which identical treatments produced varied results was surprising. The results indicate also the extent to which any chemical or chemicals, method of application or concentration must be evaluated not only in terms of fruit set, size, and quality but also with respect to the particular environmental conditions prevalent during development to maturity.

An additional house (House 4) in the Ohio Greenhouse Company range was utilized for tests wholly with solutions and various types of emulsions. At the same time all the remaining houses (but one) of both establishments were commercially treated with the emulsion of indolebutyric acid .2 per cent) plus beta-naphthoxyacetic acid (50 ppm), which accounts for the term "standard" although the particular formula should not be considered "standardized" nor necessarily the most effective treatment for commercial use.

Results here presented show the outstanding effect of certain aerosol, solution, and emulsion treatments in stimulating increased yields. Increases induced by the best treatments ranged from 20 to 40 ounces per plant which, calculated on an acre basis, would amount to from 11,800 to 22,500 pounds. But even so the increase in weight does not complete the picture, since untreated fruits were variable in size, preponderantly small, often rough, wrinkled, and in general commercially undesirable, although much improved in the third cluster over the first and second.

Although from the yield viewpoint the aerosol treatments were as satisfactory as the emulsion of indolebutyric and beta-naphthoxyacetic acids, their performance in regard to hollowness and pulp development is another matter. Results in the two greenhouses were inconsistent and erratic. All the treatments that, at the Ohio Greenhouse Company were high in yield, resulted in fruits that were often oversized, ribbed, generally inflated, and frequently very hollow. Examination showed actually that the pulp was not only restricted in development but that, apparently, the radial carpel walls were frequently extended and somewhat thickened. In consequence, it was generally agreed that fruits produced by the aerosol treatments in this house were commercially undesirable. While fruits resulting from the standard emulsion showed some restriction in pulp development, it was insignificant in comparison with the fruits produced by aerosol. Since commercial plants in all but three houses were treated with the emulsion, the general acceptability of fruits so treated is evident. In the test at the Olmsted Greenhouse Company, on the other hand, fruits resulting from the aerosol treatments were very satisfactory, practically equalling those induced by the most effective solutions and emulsions (see Table VIII). Presumably this difference in pulp development in the two houses is due to the difference in air temperature and humidity. Even the untreated fruits in the houses of the Ohio Greenhouse Company were not so well filled as similar treated fruits at the Olmsted Company. Furthermore, fruits set on the first three clusters of plants in an untreated house at the Ohio Company were much poorer than those from similar, untreated plants in an Olmsted house. That cool air temperature will result in some restriction in pulp development has been previously observed. From the point of view of tomato production conditions prevalent in the Olmsted houses were more favorable, but, since differences exist in the temperatures maintained during this period it is probable that the solution or emulsion is, at present, more generally adaptable than the aerosols. It should be kept in mind, however, that only one concentration of the chemicals was tested in aerosols, and that other concentrations might give different results. Furthermore, it is also probable that the environmental conditions in the greenhouse have a definite effect upon treatment. Only further investigation under varied conditions will serve to standardize the enviromental conditions most favorable to treatment, the most effective formula, and the most effective method of application.

Although it is generally apparent that the most effective aerosol treatment contained the three chemicals, indolebutyric acid, beta-naphthoxyacetic acid, and 4–chlorophenoxyacetic acid, its superiority over beta-naphthoxyacetic acid alone was slight. The difference between them, if any, was insignificant from the yield viewpoint, but the aerosol containing the three chemicals was slightly superior in its effect upon pulp development. At the Ohio Greenhouse Company beta-naphthoxyacetic acid produced fruits showing much less pulp development. Its effect at the Olmsted Greenhouse Company, on the other hand, was slightly superior in this respect but inferior as to color. Thus, while further work is necessary in this connection, it would appear that the aerosol treatment involving the three chemicals is slightly preferable to beta-naphthoxyacetic acid alone. In this connection the data as a whole would indicate the favorable effect of 4–chlorophenoxyacetic acid in the combination since the aerosol containing indolebutyric acid and beta-naphthoxyacetic acid was inferior to the combination of the three chemicals. Furthermore, indolebutyric acid alone in aerosol was of no value for flower treatment in view of the small and inferior fruits produced. As stated before other concentrations might possibly have produced different results.

The standard emulsion fulfilled expectations in both houses. At the Ohio Greenhouse Company it was second in yield in comparison with the best aerosol treatment, while at the Olmsted Greenhouse Company it was surpassed only by the water solution of the same chemicals and by an emulsion of half the concentration of indolebutyric and beta-naphthoxyacetic acids. Fruits obtained from the solution and the emulsion of the two chemicals were uniform, medium to large in size and excellent in appearance. Another point of interest is the fact that the data definitely indicated the superiority, in general, of the combination of indolebutyric and beta-naphthoxyacetic acids to either one used separately, whether in water solution or in emulsion. This conclusion was substantiated also by tests in the adjacent house (House 4, Ohio Greenhouse Company) from which the data will be presented elsewhere. The fact that the water solution produced such creditable results is one of the practical advantages of the tests. In view of the tendency of the emulsion to clog the small orifice of the atomizer it was gratifying to find that lanolin might be omitted without any detrimental effect upon the size and quality of the fruit.

Some explanation should be made concerning the inconsistent effect of the various treatments upon pulp color. In the first place, the greenish tinge of the gelatinous pulp indicates a slower rate of development than that which occurs in other portions of the fruit. At no time during the ripening can one detect any differences in the taste of this greenish pulp and eventually it turns a darker red. But it has been observed for some time that fruits induced by indolebutyric acid treatment are more likely to show this greenish color, which may be apparent also in fruits developing without treatment (see Tables IV and VIII). In this connection it is interesting to note that at the Ohio Greenhouse Company where the aerosol treatment resulted in relatively poor pulp development, it was, nevertheless, more generally red. On the other hand, where a greater proportion of the fruits were filled with gelatinous pulp, as at the Olmsted Greenhouse Company, a greater proportion of the fruits showed the green-tinged pulp. Apparently there is some association between extensive pulp development in treated fruits and the delay in appearance of the red color. Furthermore, even beta-naphthoxyacetic acid, which is probably productive of better pulp color than indolebutyric acid, may show, under certain conditions, this same greenness. It should be pointed out that this tendency is more conspicuous in the results obtained from the earlier-treated clusters and that it did not interfere in 1945 with the commercial value of the fruits at the Ohio Greenhouse Company.

As previously pointed out, the data show a compensating effect on fruit set and yield in the fourth to six clusters of the treated plants in comparison with the same clusters of the untreated plants. This negative compensation, while commensurate in part with the greatly improved early yield, was not sufficient to offset the early gain. Moreover, it can reasonably be concluded that treatment above the third cluster would have continued to show the superiority of treatment. In house 4 (Ohio), to which reference has already been made, the set and yield of the fourth cluster was greatly improved over the untreated checks despite the high yield in the first three clusters. The total number of fruits set in the first three clusters averaged 7.3 as compared with 3.3 on the untreated. The fourth treated cluster averaged

4.1 as compared with 3.0 for the untreated. It is probable that continuous treatment would have maintained the superiority for several clusters above the third. This supposition is, in fact, supported by observations made by growers who treated all clusters on vigorous, rank-growing plants. Very satisfactory sets developed on all such clusters, a fact which lends support to the conclusion that continuous treatment may be necessary if optimum results are to be obtained. Evidence is accumulating, however, that favorable effects of continuous treatment are more likely to be obtained on plants with large leaf surface and thick stems. The exhaustion of fruiting can develop on a treated as well as on an untreated plant if the load becomes too heavy.

SUMMARY

Growth-regulating substances were applied in solutions, in emulsions, and in aerosol to flowers of the first three clusters of tomato plants grown in two greenhouses in the Cleveland, Ohio area. Indolebutyric acid and beta-naphthoxyacetic acid were tested chiefly, although 4–chlorophenoxyacetic acid was included in one aerosol treatment. The principal conclusions follow.

The most effective aerosols, solutions, and emulsions resulted in much earlier fruit production and in yield increases of 20 to 40 ounces per plant, or at the rate of 11,800 to 22,500 pounds per acre. This increase in yield was even more satisfactory than the figures indicate since fruits on the first three clusters of untreated plants were generally variable in size, small, and often commercially undesirable.

The number of fruits in the first three clusters was increased 37 to 70 per cent by the most effective treatments. In the best treatments the size of the fruits was increased 34 to 70 per cent as compared with the untreated

The results of the best aerosol treatments were inconsistent insofar as pulp development was concerned. In the tests at one location the fruits were often over-size, ribbed, inflated, and showed such poor pulp development that they were in general commercially undesirable. In the tests in another greenhouse range, under different temperature and humidity conditions, aerosol treatments produced excellent fruits showing very satisfactory pulp development. The most satisfactory aerosol treatment, from all points of view, contained the three chemicals, beta-naphthoxyacetic acid, indolebutyric acid, and 4–chlorophenoxyacetic acid. Beta-naphthoxyacetic acid used alone was second in value. Indolebutyric acid, as used in these tests, was very unsatisfactory when used alone. Repeated (three) applications of aerosol were more satisfactory than one application per cluster.

The water solution of indolebutyric acid or of beta-naphthoxyacetic acid was as effective as the lanolin emulsion of the same concentration.

Beta-naphthoxyacetic acid in water solution was not quite so effective as the water solution or the emulsion containing indolebutyric acid in addition.

Some compensating decrease of yield occurred in the three succeeding untreated clusters of the treated plants, but it was not sufficient to offset the outstanding effect of treatment, and consequently there was an increase in the total yield of the six clusters from which data were taken. Results indicate that treatment of the fourth cluster would have continued the superiority of treated over untreated clusters. It is probable that further treatment above the fourth would have done likewise. This point requires further investigation.

Environmental conditions, such as air temperature and humidity definitely affect the results obtained from applications of chemicals in aerosols, solutions, or emulsions. This factor must be taken into consideration before drawing conclusions as to any chemical, concentration, or method of application. Additional work is necessary relative to the possibility of replacing the present time-consuming method of treatment with the more practical and efficient aerosol applications.

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The Value of Several Petroleum Products as Selective Sprays for Weeding Carrots[1]

By R. D. Sweet, R. Kunkel,[2] and G. J. Raleigh,[3]
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The use of oil sprays for the selective weeding of carrots has become a widespread practice in New York as well as in California where the method was first used.

Several different oils have been advocated. Crafts and Reiber (1) and Raynor (3) recommended stove oil for California. Lachman (2) suggested several solvents for Massachusetts. The authors reported (4) variable results with fuel oil and kerosene in New York.

The purpose of these studies was to determine (a) which oils are best suited to New York conditions, and (b) what physical and chemical properties of oils are closely correlated with their value as selective sprays for weeding carrots.

Materials and Methods

Stove oil, fuel oil, kerosene, insecticide base oil, industrial solvent, D. D. T. Solvent, and dry cleaning fluid were used. At least two samples representing different sources of the above types of material were included in the tests. Practically all of the oils were applied at several stages in the growth of carrots and weeds. A small knapsack sprayer was used for the outdoor experiments and an atomizer on a compressed air line was used in the greenhouse tests. The rate varied from 75 to 150 gallons per acre depending on the size of the plants to be sprayed. In each instance sufficient oil was applied thoroughly to wet the foliage of both carrots and weeds.

Experimental Results

A summary of the results obtained in both the greenhouse and field experiments with the various oils together with the boiling range, aromatic content and weed killing value of each material is presented in Table I.

The toxicity of the oils is reported on the basis of "chronic" and "acute" injury as defined by Crafts and Reiber (1). They class as "acute" that injury which occurs within a few hours after spraying and which is usually restricted to the plant parts actually hit by the spray. They class as "chronic" that injury which occurs several days after spraying, and which may affect tissues other than those actually covered by the spray. Both carrots and weeds are susceptible to chronic injury but carrots are fairly resistant to acute injury.

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TABLE I—THE EFFECT OF BOILING RANGE AND AROMATIC CONTENT ON THE VALUE OF SEVERAL PETROLEUM PRODUCTS FOR SELECTIVE WEED KILLERS IN CARROTS

Number	Number of Samples	Boiling Range Degrees F	Aromatics Per Cent by Volume	Toxicity				Persistance of Flavor
				Chronic*		Acute*		
				To Weeds	To Carrots	To Weeds	To Carrots	
				Stove Oil				
1	1	335-570	—	Slight	Slight**	Severe	Slight**	2 to 3 months
				Fuel Oil No 2				
2	2	400-600	14-20	Slight	Slight**	Severe	None	2 to 3 months
				Kerosene				
3	5	350-525	10-14	Slight	Slight**	Severe	None	1 to 2 months
4	2	350-525	0-3	Slight	Slight**	Slight	None	1 to 2 months
				Insecticide Base				
5	2	370-485	0	None	None	None	None	—
				Industrial Solvent				
6	2	300-400	50-60	None	None	Severe	Severe	2 to 3 weeks
7	1	300-425	15-18	None	None	Severe	None†	2 to 3 weeks
8	1	345-415	85-90	None	None	Severe	Severe	2 to 3 weeks
				DDT Solvent				
9	1	420-550	85-90	Slight	Slight**	Severe	Severe	—
10	1	580-760	95-100	Severe	Severe	Severe	Severe	Indefinite
11	1	500-640	95-100	Moderate	Moderate	Severe	Severe	Indefinite
12	1	390-530	80	None	Slight**	Severe	Severe	—
				Dry Cleaner				
13	6	300-400	10-15	None	None	Severe	None	2 weeks
14	1	300-400	6-8	None	None	Moderate	None	2 weeks

*Chronic injury is slow acting and may affect tissues not covered by sprays whereas acute injury is quick and is usually restricted to tissues covered.

**Slight injury when carrots have at least two true leaves, but moderate to severe on carrots in seed-leaf stage.

†None when carrots had two or more true leaves, but slight injury occurred when carrots were in the seed-leaf stage.

An ideal oil spray would cause no injury to carrots, leave no residue in the soil, and no objectionable flavor in the carrots. It also would be fairly inexpensive and readily obtainable by growers.

As is shown in the table, materials No. 7 and 13, an industrial solvent and dry cleaning fluid, most nearly approach these specifications.

The data also show that a high boiling range, end point above 550 degrees F, usually resulted in chronic injury and that an aromatic content of 10 to 15 per cent by volume was severely toxic to weeds but not to carrots. These data substantiate the work of Crafts and Reiber (1) and Lachman (2).

Although persistence of off-flavors in the harvested crops was directly correlated with the boiling range, the odor of the material applied also influenced persistence. Stove oil and fuel oil were two of the most obnoxious in this respect, whereas dry cleaning fluids and industrial solvents were the least offensive.

DISCUSSION

Oils having an initial boiling point below 300 degrees F, although sometimes satisfactory for weed control, are not recommended because they usually have a flash point below 100 degrees F. Such materials are dangerous to use. Other highly aromatic materials having a high boiling range, above 550 degrees F, resulted in chronic injury and were unsatisfactory to use.

The oils having a relatively high aromatic content were diluted with either a low aromatic kerosene or an insecticide base oil until they were no longer toxic to carrots. Satisfactory selective sprays were obtained with materials Nos. 6, 8, 9, 11 and 12 (Table I) when the dilution resulted in an aromatic content of approximately 15 per cent. This was about the same aromatic content of several kerosenes, solvents, and dry cleaners which performed well.

Solvents and dry cleaners could be safely applied to carrots in the seed-leaf stage, but the kerosene, fuel oil, and stove oil caused severe injury unless the carrots had at least two true leaves. This injury is probably due to the high boiling range of these materials and the resulting low evaporation rate.

The variable results obtained by the authors (4) are explained by the variable aromatic content of the oils which were used in their preliminary work. For example, kerosene with an aromatic content of 10 to 14 per cent proved satisfactory but that having only 3 per cent or less did not kill weeds.

SUMMARY

Petroleum products having an aromatic content of 10 to 15 per cent by volume kill weeds but do not injure carrots provided the boiling range is not higher than about 300 to 550 degrees F. A somewhat lower range of 300 to 400 degrees F is more satisfactory because of less persistence of objectionable flavors. Oils meeting these specifications can be used at any period early in the growth of the crop because carrots still in the seed-leaf stage are tolerant of them.

Dry cleaning fluids having 10 to 15 per cent aromatics by volume are recommended for weeding carrots because they cause no injury to carrots, leave no residue in the soil and result in practically no objectionable flavor in the carrots. They are readily obtainable at relatively low cost (13–16 cents) per gallon in drum lots. Certain industrial solvents also are satisfactory but are more difficult to obtain and are somewhat more expensive.

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A Key to the Horticultural Groups of Varieties of the Southern Pea, *Vigna Sinensis*

By William H. Brittingham, *Texas Agricultural Experiment Station, College Station, Tex.*

The table varieties of the cowpea, *Vigna sinensis,* are here referred to as "southern peas". The commercially available varieties of southern peas can be arranged in 13 horticultural groups, based almost entirely on seed size, shape, color and color patterns. The only exception is, of course, those varieties comprising the Purple Hull Group.

During the past three years, the Texas Agricultural Experiment Station has conducted yield trials involving 67 seed lots representing all available southern pea varieties. It has been noticed that certain characters in the young plant are invariably associated with certain of the horticultural groups, making possible, in many cases, an early identification of the horticultural group being grown.

The following key to the 13 horticultural groups of varieties of the southern pea has, as far as possible, made use of those qualitative characters that allow the earliest possible identification in the field. In some cases, the variety as well as the group may be determined in this way.

Field Key to the Horticultural Groups of Varieties of the Southern Pea

A. Trailing, viny plants, strongly climbing if given support; pods 15 to 30 inches long, flabby and inflated, shrinking about the widely spaced elongate kidney-shaped seed when dry...........ASPARAGUS BEAN GROUP
(*Vigna sinensis* subsp. *sesquipedalis*) Variety: Yard long

AA. Procumbent, bushy, or erect plants, often twining at tips but not true climbing; pods 3 to 12 inches long, never flabby or inflated and not shrinking about the more or less crowded seed when dry.

B. Purple anthocyanin pigment on stems, usually restricted to nodes; also purple on leaves, at least at pinnae-petiole juncture; flowers pale violet or purple; seed pigmented, solid, speckled, or in an "eye" pattern at hilum.

C. Purple at tip of peduncle, on calyx, and on immature pods, at least at tips.

D. Flowers pale violet; seed with "small eye" pattern.

E. Purple intense on tip of peduncle, sometimes extending down it; intense purple completely covering calyx, mature pods deep purple; seed with buff or maroon eye........PURPLE HULL GROUP

Varieties: Many listed as Purple Hull
Jackson Purple Hull (early, bunch type, maroon eye)
Bunch Purple Hull (same as Jackson Purple Hull)

EE. Purple not intense on tip of peduncle and restricted to tip; purple on calyx not intense and confined to dorsal side; mature pods yellow; seed with black eye.

F. Pods 5.5 to 6.5 inches long; seed crowded in pod
BLACKEYE CROWDER GROUP

Varieties: Many listed as Blackeye Crowder
Alacrowder

FF. Pods 6.5 to 8.5 inches long; seeds not crowded in pod
BLACKEYE GROUP

Varieties: Many listed merely as Blackeye
Many listed as Large Blackeye
California Blackeye
Early Ramshorn Blackeye
Giant Ramshorn Blackeye
Virginia Blackeye (large, flat seed)
Extra Early Blackeye (early, bunch type, small seed)
California Blackeye No. 5 (nematode resistant)
California Blackeye 8152
(wilt and nematode resistant)

DD. Flowers purple; seed solid color or uniformly speckled.

G. Pods 5.0 to 6.5 inches long, very thick; seed very crowded in pod; seed solid black........BLACK CROWDER GROUP

Varieties: Listed as Black Crowder

GG. Pods 7.0 to 8.5 inches long; seed usually only moderately crowded in pod; seed finely speckled blue
SPECKLE CROWDER GROUP

Varieties: Some listed as Speckle Crowder
Blue Goose (syn. Gray Goose, Taylor, Gray Crowder)

CC. No purple on tip of peduncle, on calyx, or on immature pods.

H. Flowers pale violet; seed patterned.

I. Seed with "small eye" pattern in some shade of buff or brown.

J. Pods 5.0 to 6.5 inches long; seed crowded in pod; midseason maturity..BROWNEYE CROWDER GROUP

Varieties: Many listed as Browneye Crowder
Pinkeye Crowder
Also some misnamed (e.g. "Sugar" Crowder)

JJ. Pods 8 to 11 inches long; seed not crowded in pod; usually late maturity.........BROWNEYE GROUP

Varieties: Alalong
Todd
Dixie Queen

II. Seed with red "Holstein eye" pattern
SPOTTED CROWDER GROUP

Varieties: Calico (syn. Hereford)
Also some misnamed (e. g. "Red Speckle" Crowder)

HH. Flowers purple; seed solid buff or brown
BROWN CROWDER GROUP

Varieties: Many listed as Brown Crowder
Some listed as "Sugar" Crowder
Silver Skin Brown Crowder
Jackson 21 (pods longer, seed moderately crowded, darker brown; earlier maturity)

BB. No purple anthocyanin pigment anywhere on plant; flowers white, seed uniformly cream-colored or white.

K. Pods held erect, 3 to 4 inches long, cylindrical, not over one-fourth inch in diameter; seed small, almost spherical, very crowded in pod
CATJANG GROUP

(*Vigna sinensis* subsp. *cylindrica*) Variety: Lady Cream (syn. Rice)

KK. Pods pendant, 5.0 to 7.5 inches long, over ¼ inch in diameter.

L. Pods 5.0 to 6.0 inches long; seed crowded in pod—CREAM CROWDER GROUP

Varieties: Many listed as Cream Crowder
Short-podded Cream

LL. Pods 6.0 to 7.5 inches long; seed not crowded in pod.................. .....CREAM GROUP

Varieties: Some listed as Cream Pea
Long-podded Cream
Early Bush Cream
Sumptuous Conch Pea

Forecasts from an Incomplete Experiment on Asparagus[1]

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From the first cutting in 1929, this experiment on asparagus ran 10 years before being interrupted by wartime scarcity of labor. According to the original plan, the life of the experiment was to have been 20 years or longer, the object being to learn how late in the season cutting could be continued with profit to the canner and his producers. The purpose of this study is to make some forecasts as to what might have happened had the experiment been continued.

In 1927 randomized blocks with six replications were planted with 2-year crowns. On one of the six plots in each block, cutting was terminated May 1; on others the final cuttings were at bi-weekly intervals, May 15, June 1, and so on, to July 15. The results have been reported from time to time by Haber (3, 4, 5), and Snedecor (6, 7).

The main features of the experiment are shown in Fig. 1. In plots where cutting ceased before June 1, the yields were clearly too small to be profitable. Plots cut until July 15 were so depleted in vitality that harvesting was suspended in 1934; while these plots later made some recovery, such severe cutting is evidently not feasible. This leaves the three dates, June 1, June 15, and July 1, to be made the basis for forecasts. Could these results have been foreseen, the more extreme dates would have been omitted and the cessation of cutting would have been confined to weekly intervals during June. This would have provided a broader basis for inferences about the future.

In every year, cutting until June 15 produced greater yields than the cutting which ended June 1. Nevertheless, it is worth examining the differences to discover any trends on which to base forecasts. In Fig. 2 are plotted the differences in the average yields of the two sets of six plots. These differences increase somewhat erratically from a low of 51 ounces per plot in 1930 to 229 ounces per plot in 1938. The analysis of variance of the 60 differences (six differences in each of 10 years) is shown in Table 1. Linear and parabolic trends have been fitted to the data by the use of the Σ values for orthogonal polynomials (1, 2).

Although the linear trend is significant ($F = 56{,}026/2{,}107 = 26.59$, df. = 1 and 5), examination of the graph (Fig. 2) leads to the conclusion that it may not have persisted after the first few years during which the plants were attaining free productivity. In the final 6 years, the linear trend was nonsignificant, no more than seasonal fluctuations being indicated.

The deviation from linear trend is not significant ($F = 4{,}118/2{,}320 = 1.77$, $F_{.05} = 6.61$). The sample trend suggests that the superiority of the June 15 cutting date is being gradually lost: at some time in the future those plots would yield no more than those out to June 1. But the evidence for this is not strong. So far as this experiment was

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[1] Journal Paper No. J-1374 Project 316, Iowa Agricultural Experiment Station.

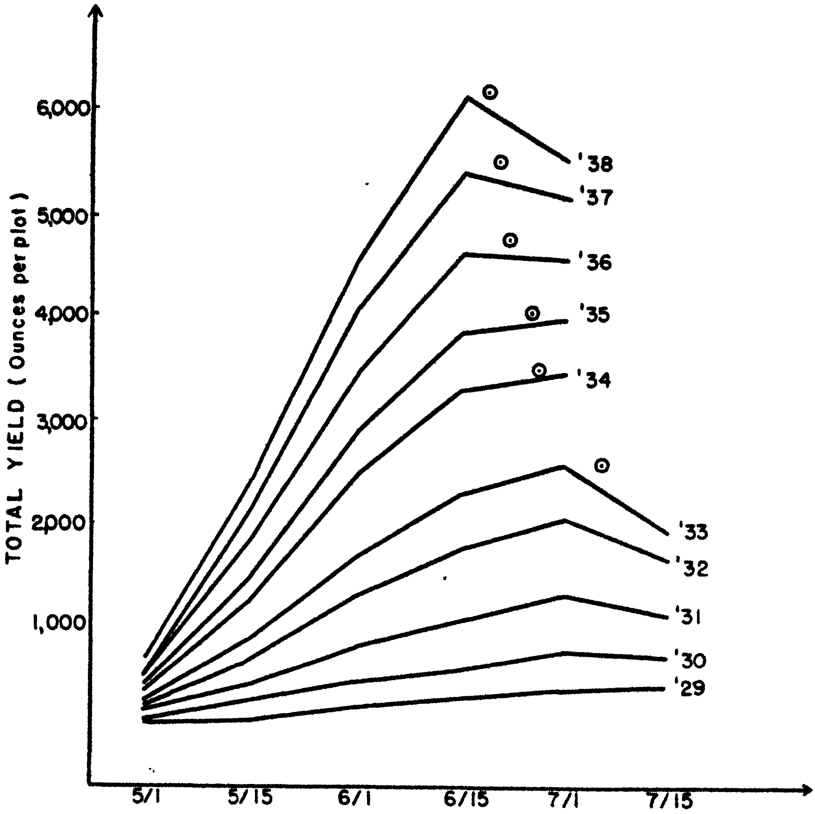

FIG. 1. Accumulated yields (ounces per plot)

carried, there was no definite decline in the difference in yields, June 15-June 1. Hence it is concluded that the evidence so far as it goes is only this; for maximum yield over a 20-year period, cutting should be continued at least until the middle of June.

TABLE I—ANALYSIS OF VARIANCES OF 60 DIFFERENCES, (YIELDS TO JUNE 15 — YIELDS TO JUNE 1)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Years: Linear	1	56,026	56,026
Parabolic	1	4,118	4,118
Remainder	7	32,384	4,626
Total	9	92,528	——
Blocks	5	66,103	——
Years × Blocks			
Linear	5	10,535	2,107
Parabolic	5	11,602	2,320
Remainder	35	20,279	579
Total	45	42,416	——

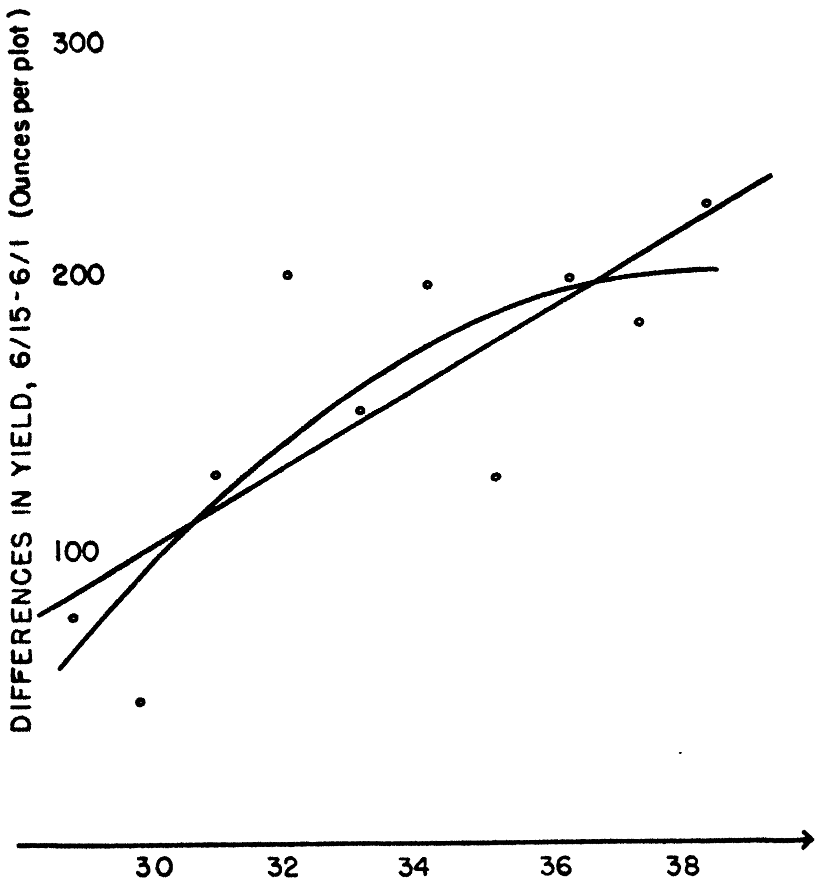

FIG. 2. Differences in yield June 15–June 1 during 10 years. Linear and quadratic trends.

The differences in yield, (July 1-June 15), offer a striking contrast to those discussed above. The graph (Fig. 3) shows the progressive deterioration of the July 1 cuttings as compared to the June 15. By 1936, even the total production of the former had fallen below that of the earlier cutting date. In 1939 the growth of the 7/1 plots was so scant that cutting had to be discontinued in the middle of June. There is no doubt that for maximum production during the ordinary life of an asparagus planting, cutting must cease before July 1.

The analysis of variance of the 60 differences, (July 1-June 15), is shown in Table II. Not only the linear regression, but the quadratic as well is significant.

From the foregoing, it is clear that the June 15 cutting date is near the optimum. Before attempting a more critical evaluation of this

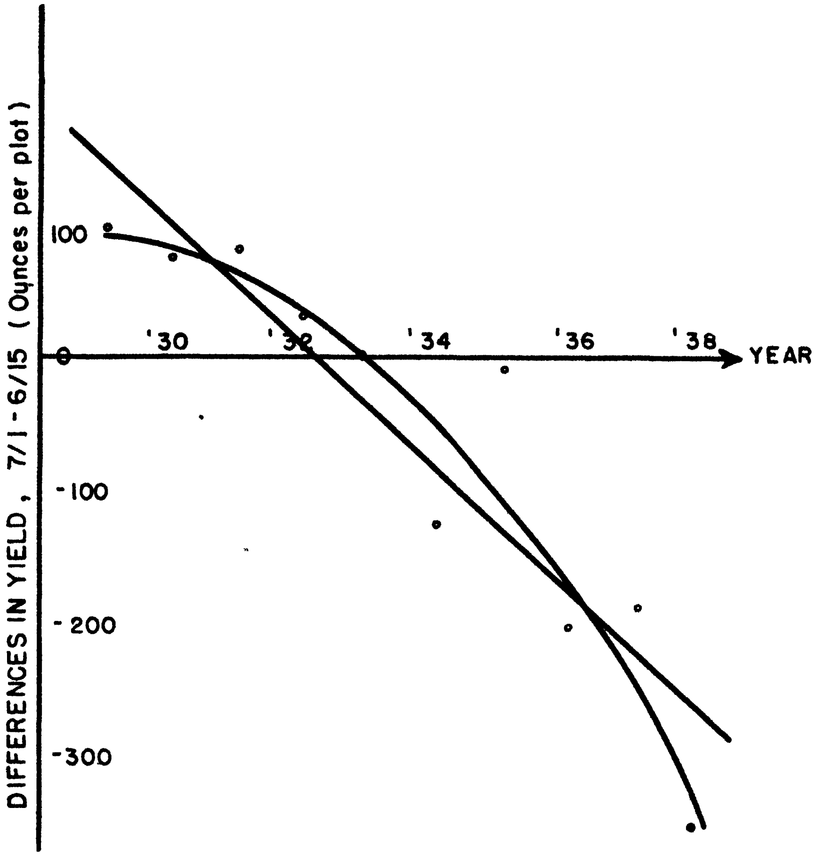

FIG. 3 Differences July 1-June 15 with linear and quadratic trends.

optimum date, consideration should be given to the trends in the yields of plots cut until June 15 (Fig. 4). From 1933 onward, there is no evidence of deviation from a linear trend in any of the plots. The low-yielding Plot III has a slightly less annual yield than the others,

TABLE II—ANALYSIS OF VARIANCES OF 60 DIFFERENCES IN YIELD (JULY 1 — JUNE 15)

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Years: Linear	1	537,345	537,345
Quadratic	1	34,927	34,927
Remainder	7	62,081	8,869
Total	9	634,353	——
Blocks	5	807,517	——
Years × Blocks			
Linear	5	17,392	3,478
Quadratic	5	20,749	4,150
Remainder	35	38,380	1,097
Total	45	76,521	——

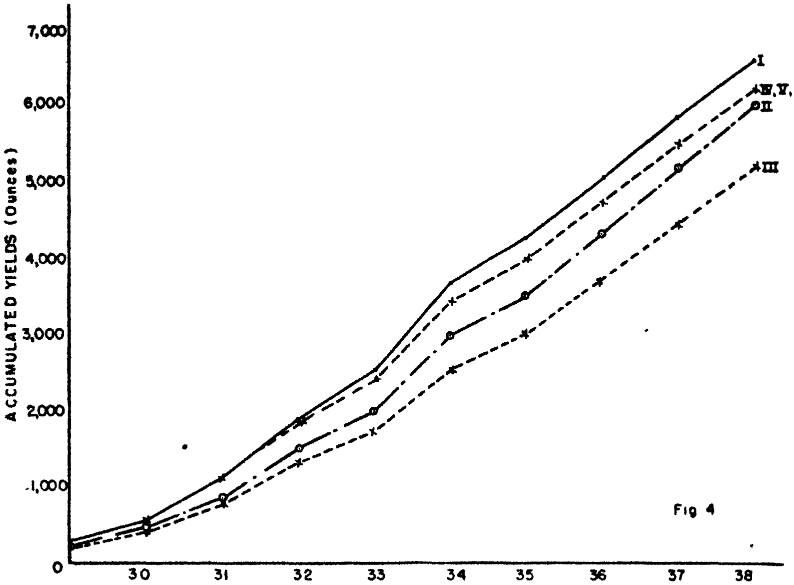

FIG. 4. June 15 accumulative totals by block.

resulting in a more gradual rise in total production; but in none of the plots is there indication of declining yield due to aging.

According to popular opinion, the economic life of an asparagus bed is 20–25 years. What happens, then, during the period following the end of the present experiment? When do the June 15 yields begin to decrease and how fast do they decline? This experiment contains no evidence on these questions. In the forecasts to follow, the assumption must be made that aging affects all plots in a similar manner — so that the optimum cutting date is not disturbed. If aging consists of gradual approach of the growing points to the surface and inefficient distribution of the roots with consequent decrease in the size of the shoots, this assumption seems tenable. If it should turn out that earlier cessation of cutting delays the aging process, then the optimum date of cutting may occur before that arrived at.

Under the assumption just stated, an indication of future trends may be gained by examining the estimated dates of cutting which would produce the maximum accumulated yields during increasing numbers of years. These optimum dates will be taken as those corresponding to the maxima of parabolas fitted each year to the total production for the three dates, June 1, June 15, and July 1.

In Fig. 1, the circles indicate the maximum point for each year's accumulated production, beginning in 1933. In that year, the estimate is that the total production (1929–1933 inclusive) would have been 2,579 ounces per plot if cutting on all plots had always ceased on July 7. With the 1934 harvest, this optimum date had receded to June 27, and it had reached June 19 at the end of the 10th year.

If these optimum dates are plotted against year of harvest, a hyperbolic trend becomes evident. A curve was fitted to the points, then used to forecast the cutting dates for maximum total production through the 10 years following the end of this experiment. Fig. 1 shows that only a slight recession can be expected after 1938: after 20 years of harvest the optimum reached June 17–18, only a day or two earlier than the optimum date for the first 10 years. Even if harvesting were continued considerably beyond 20 years, cutting to June 17 appears to be indicated.

The question may be asked, "Is the optimum cutting date related to soil fertility?" Table III shows the total yield and optimum 10-year cutting date for each of the 6 blocks. With the exception of that for Block III, the dates all fall close to the average, June 19, with no evident correlation between yield and date ($r = -0.09$). Assuming normal distribution in the population, it may be said that the probability is 50 per cent that the population mean lies between June 17 and June 22, and that, so far as this experiment is competent, soil fertility does not modify the date of cutting for maximum 10-year yield.

Also shown in Table III are the estimated optimum cutting dates for 20-year yield. Block III furnishes no basis for such an estimate because no maximum yield was indicated except in the 10th year. The reason was that the June 15 plot in this block was the poorest of all the June 15 plots so that the several cutting date yields in this block went up steadily through July 1 with no sign of decline. As with the 10-year optima, there is no sign of correlation between yield and 20-year optimum cutting date, and these dates cluster closely around the 17th and 18th of June.

TABLE III—TOTAL YIELD (OUNCES PER PLOT) AND ESTIMATES OPTIMUM CUTTING DATE OF SIX BLOCKS

Block	Yield	Optimum Cutting Date	
		10 Years	20 Years
I	946	Jun 18	Jun 17
II	854	Jun 17	Jun 22
III	856	Jul 20	—
IV	896	Jun 20	Jun 18
V	880	Jun 19	Jun 17
VI	954	Jun 24	Jun 20

The apparent independence of yield and optimum cutting date seems rather surprising, so another approach was attempted. For each of the three cutting dates, the highest yielding plots were assembled, regardless of the field position; also, the three lowest yielding plots. The optimum 20-year cutting date was estimated for each triplet with the results shown in Table IV. The difference between the two estimated optima is negligible as compared to the experimental error; and the same is true for the difference between the average of these two sets and the average for the entire experiment. Again there is no evidence of correlation between yield and optimum cutting date.

If the results of this experiment prove to be generally applicable, the problem of managing the sources of production for processing is

TABLE IV—AVERAGE YIELDS (OUNCES) AND OPTIMUM 20-YEAR CUTTING DATES OF TWO SETS OF PLOTS, THE HIGHEST YIELDING AT EACH DATE AND THE LOWEST YIELDING

	Mean Yield of 3 Plots	Optimum 20-Year Cutting Date
Highest	5.898	Jun 17
Lowest	4.796	Jun 19

simplified. The canning season can be planned to end on the same date for all plantings — about the middle or end of the third week in June according to the present findings. The maximum production may be attained, not by varying the date of final cutting, but by increasing the productive capacity of the fields.

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Some Post-War Problems of Southern Horticulture[1]

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DURING the last year or so of the war there was much talking and writing about post-war planning. This activity afforded an excellent opportunity for theorizing agriculturists to "let off steam". It also afforded an opportunity for honest-to-goodness, down-to-earth crop and livestock experts to get a word in here and there reflecting information gathered in the school of experience with "dirt-farmer" problems.

Now that the war is over—the shooting part of it at least—there is little talk about post-war plans. Maybe it is too soon after the war for us to really be in the "post-war" period for which so many plans were devised. The fighting has stopped, and it stopped so much more suddenly than most of us expected that we were not prepared for the impact brought about by its sudden close. Be that as it may, it would seem that now is a good time for southern horticulturists to do a bit of inventory work, a little "stock-taking" as the merchants say.

It is still our job as a nation to furnish an abundance of food to the working millions of America and to produce some surplus to help the more needy people of the world. There is every reason to guard against disastrous surpluses which may contribute little to feeding the people, but which entail enormous waste of labor and materials and might bring disaster to thousands of growers. Some careful planning would certainly seem to be in order. Would not we do well to take a look at some of the problems that we are soon to face in southern horticulture?

I would like to call your attention to some of these problems; not for the purpose of telling you what their solutions are. The problems themselves may suggest the solutions. You know that they exist. I just want to hold them up before you at this time so that we can take a look at them in their proper perspective.

As I see our horticultural problems, they may conveniently be placed in three categories: (a) Those that relate to production, (b) those that relate to marketing, and (c) those that relate to education.

These problems obviously are so closely interlocked, interwoven, and inter-related that it is difficult to think about one without thinking about one or both of the others. We must *produce* in order to have anything to *market;* and without an *educational* program, how are we to have trained personnel to produce or market, or carry out any action programs?

First, let's take a look at some of our problems of production.

I would like to ask the question: What effect is the war-time victory garden program going to have upon production of garden products?

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[1] Address of the retiring chairman delivered at the seventh meeting of the Southern Section of the American Society for Horticultural Science, New Orleans, La. February 6, 1946. A contribution from the Mississippi Agricultural Experiment Station, published with the approval of the Director— Journal Article 117 (N.S.)

During the victory garden campaign years when everybody was talking about gardens there were, for example, over 400,000 gardens in Mississippi each year. During these years added emphasis has been placed upon 4-H club gardens, and the National Junior Vegetable Garden Contest. This means that many more gardens have been grown by many more people than were ever grown before. Have these new gardeners learned to appreciate the value of fresh vegetables to the extent that they will want more of them from now on? Will they quit gardening and buy more than heretofore? Will these buyers be more "choosy" about the "garden freshness" of the products they purchase? These questions pose problems of garden crop production.

Another production factor which has had much attention during the war years has to do with pest control, including weed control.

You are all familiar with the sensational results concerning the wonder chemical DDT. Both popular and technical literature has been filled with information and mis-information about this material. There are also the "Lethanes", the "Dowfumes", "Sinox", "Fermate", "DD Mixtures", and other recent names such as "Deenate", "Deenol", all advertised as pesticides. Out of the work of manufacturers and sellers of these materials and that of the state and federal research groups, undoubtedly has come improvement in positive methods of direct pest control.

Current and war-time research has contributed materially to improvement in methods of applying insecticides by the use of aircraft. Concentrated sprays, improved dusts, and improved distributing devices have further demonstrated the practicability of the airplane method of application of insecticides. This method of application is already a standard practice in certain areas. Can it be expanded?

Recent research has developed methods of dispersing insecticides by means of "Aerosols". The ease with which these materials may be applied has opened up new fields of pest control. It has been thought that devices developed in connection with the war effort may make it possible to spray insecticides in open areas by the aerosol method. How can this principle be fully applied and utilized in controlling horticultural crop pests in the South? Is it possible that research will indicate the feasibility of cooperatively controlling certain of our crop pests over wide areas by a smoke screen?

What about weeds? Can we hope that the weed-killing chemists are soon to give us specific selective weed killers which will replace the labor of hand hoeing many crops? A quick survey of recent literature shows that definite progress has been made in that direction. Are we looking into this thing eagerly enough? What is the effect of weed killing chemicals on the growth and development of vegetable crops? How do they affect quality? How do the chemicals kill the weeds? At what stage of growth are weeds most susceptible to injury? How do environmental factors influence the action of weedicides? Do weed killing chemicals influence the productivity of the land? These and other questions must be answered before definite weed control programs with chemicals can be formulated. Some are even burning the weeds out of certain crops now! Probably more has been done on cotton cultivation by flame than on any other crop, but tests are being made with flaming vegetable and nursery crops. Celery and carrots are reported to have been successfully flamed, and there is already available a one-man push-type home gardener's flame cultivator! How soon we will substitute the torch for the hoe I would not hazard a guess, but I am sure there are unexplored possibilities. Full page advertisements of the "Sizz-Weeder" are already in print.

Now let us take a look at the question of machinery. Labor and machinery are so closely related that it is difficult to consider them separately. Machines are usually labor-saving in their effect upon crop production, although there are also other advantages in the use of machinery for many operations on the farm.

In addition to the flame cultivator there are in development machines that may block-out vegetable crops that require thinning, thus affecting a greatly reduced labor requirement for such crops. Can this be applied to any of our southern crops? Then there are experiments under way testing methods of fertilizer application, the results of which may involve improved or changed mechanisms for their proper application. Examples are deep application, "plow-sole" application, side-placement, liquid form materials, and anhydrous ammonia. Workers in horticulture pioneered in research with the placement of dry fertilizer materials, and the methods developed have been largely translated to grower practices. There are undoubtedly, however, yet some places where demonstration of placement results could profitably be done. How about the more recent "plow-sole" and deep methods of application? Have we tested them sufficiently to know what these may contribute in the way of increased yields or net profits or savings in labor and materials? Some of us have been testing liquid fertilizers, not only the so-called "starter solutions", which can conveniently be applied simultaneously with machine setting of transplanted crops, but also tests are being extended to include ammonia liquor as a part of the main fertilizer. Maybe this work will show us wherein we can machine-place our top dressings of nitrogen much cheaper by using concentrated ammonia liquor than by the ammonia or nitrate salts. Have we exhausted these possibilities by adequate tests? Are we working closely enough with the engineers to be sure of the proper machine development for the most economical application of such materials? How about anhydrous ammonia? Are we testing this material enough in our horticultural program to be prepared to answer the questions coming up about it? Considering the reputed capacity of the ammonia plants which were developed for war purposes turned to fertilizer use, this form of nitrogen ought to be very low in first cost. Can we make use of it in the gaseous form? Will there be developed suitable machines and methods for this material to be practicable as a fertilizer to be used by our small-acreage truck farmers? Or, will it require such elaborate mechanisms that only the big plantation operators will have the capital to make use of it? Will all of these recent developments in materials and associated machinery for their use mean changes in cultural practices for our growers? Will they mean a saving in man-hours per acre for any of our crops? These are questions somebody may need to answer before long.

In addition, there are the recent developments in tillage, spraying, dusting, and harvesting machinery which may greatly affect the "how to do" of our horticultural crop production. Will the "waggle-tail" duster, developed by the U. S. Department of Agriculture for special use in their insect eradication campaigns, be adapted for general use in vegetable and fruit pest control? What about the advertised tree sprayers of which it is claimed that one-man operators can simply drive the self-propelled rig along side the trees enveloping them with a fine mist, effecting complete coverage without halting the equipment?

Some growers claim that certain crops cannot be economically sprayed or dusted and therefore breeders are called upon to produce resistant varieties, else the growers go out of business. Maybe some of these mechanizations can be used to reduce the cost of direct controls and probably mean the difference between profit and loss for growers of some crops.

How about developments of mechanical harvesters for horticultural crops? Machines are available for some crops but are they being made full use of by our growers? Are we trying out these machines as much as we should? Is enough work under way to insure the proper demonstration of these harvesting machines? Another question is how may the use of these machines generally affect grower practices, especially those before the harvest? If harvesting by machines becomes generally accepted by the growers, how may this affect varieties, cultural practices, market quality? We may find ourselves looking for a variety of sweetpotatoes, for example, that can be dug mechanically without serious damage to the marketable grade, because labor for hand methods of gathering may not be available. We may find ourselves looking for strains of other crops specifically adapted to mechanical harvesting.

Another important problem we may consider is the development of better strains and varieties of crops. In the battle between new varieties of crops and plant diseases and insects, the plant breeders are forging ahead, and particularly in the last decade, the South has made significant progress. Newly developed varieties carry enhanced yielding capacity, superior tolerance to unfavorable soil and climatic conditions, together with resistance to pests, and higher quality for food or industrial use. The task is not finished, however, and specifications for new sorts are continuously changing. If we would keep ahead of the growers we must continue to be alert to these breeding problems.

Other production related problems may come up as these new crop varieties are introduced and grown. How about cold hardiness in peas for the early spring market? Would such a variety put more growers into profitable production? Would it force out some? How would these same growers be affected by the development of an early spring crop variety of pea that requires no staking or stringing? What would Texas and Mississippi tomato growers do if breeders gave them a variety that needs no staking for the spring crop? What are the implications involved in the prospect that there may be an important tomato canning industry in a section of the South?

Technical research on problems of plant, animal and human nutrition is opening a whole new field which may have important practical applications in the next few years. Marked variation in the nutrient contents of the same foods is being discovered. We have learned that mineral contents of crops vary with locality, and some of these contents may be adjusted by soil treatment. Other variations in nutrient content may lead to regional and area specialization in production. We have learned that crop varieties can in some instances be bred to order in vitamin content. Consider, for example, carotene in sweetpotato, ascorbic acid in tomato, cabbage, beans, and strawberries. Notable progress has already been made through breeding on these and other items in this category. Because of the added emphasis placed upon better food or proper nutrition in relation to our physical and moral well-being during the war, we are all more nutrition conscious now than before the war. Consumers of horticultural products are likely to become more and more concerned about the special and total nutritive value of those products. This places upon us the problem of developing and introducing sorts having noteworthy and superior nutritive qualities.

I have recently read a report that chemists have succeeded in snythesizing vitamin A. They actually learned how to do this during the war, but the information was kept secret until recently. Now most of our vitamins can be made in the laboratory, and this fact has been advertised and exploited extensively. I believe, however, that a large segment of the population will continue to prefer to take their vitamins by eating oranges, grapefruit, tomatoes, collards, turnips, cabbage, beans, limas, sweetpotatoes, and other foods rather than by swallowing pills or capsules.

What about processing and preservation? Probably the most striking technological advance during the immediate pre-war and war periods has been in the processing and preservation of foods. The tremendous demand for food by Britain and Russia plus the needs of our expeditionary forces, and the necessity for utilizing the limited shipping space most advantageously, required that products shipped be reduced to the smallest possible volume and weight. The Federal and State research groups at once stepped-up work on the dehydration of foods, including fruits and vegetables. Federal work on dehydration centered at the Western Regional Research Laboratory, where in a comparatively short time plans were completed for various sizes and types of commercial plants and specific information was made available on the dehydration of a dozen vegetables. This work has been the technical foundation for the rapidly expanding dehydration industry in the whole country.

What about the future of this industry? There have been a lot of guesses. Do consumers want dehydrated foods? It is doubted that many of the returning soldiers will prefer to continue with dried eggs or dried Irish potatoes, or perhaps dried milk, although the latter seems more reasonable. You have read the report of a sampling of 450 Chicago housewives by the U. S. Department of Agriculture. That study may or may not have given a clue to the future, for it probably exaggerated consumer preference because the participants may have been motivated to some extent by a mistaken desire to help by furnishing favorable results for the survey. Important also is the fact that the initial sales resistance to a new product was overcome by the samples being offered free of cost. The real significance of the results of this study, however, is that a large proportion of housewives do not appear to be definitely prejudiced against dehydrated foods, as many have assumed, and will consider them along with competitive foods when making purchases. This suggests that there may be a substantial postwar civilian market for many dehydrated foods.

Time may alter the present indicated acceptability of dehydrated foods. This acceptability will probably be affected by the following factors:

1. By consumer knowledge of future changes in the quality of dehydrated foods, relative to that of competitive products.
2. By possible reductions in the time required for reconstitution.
3. By changes in packaging.
4. By advertising and promotional campaigns.
5. By changes in relative prices.

All of this means thinking, planning, and work for southern horticulturists. Are existing varieties adapted to dehydration? Will those which are best for this purpose yield as much as others less desirable? Will the development of the dehydration industry place on us the job of developing new varieties designed specifically for that purpose? Will our growers be able to market through dehydration off-grades to an advantage for the crop as a whole?

There are other specialized processing developments in which we are interested and which pose production problems. For certain markets a considerable outlet is available for vacuum packed sweetpotatoes. However, special requirements must be met before this outlet can be expanded to any appreciable extent. The roots must be firm, more firm than any available good quality table variety. Southern packing has, on that account, been wholly of the firm but light-fleshed sort, acceptable only to a limited market. Other examples could be mentioned.

The second category of problems concerns the marketing of horticultural products. The chief reason for growers' interest in production is that they may more profitably market the crops grown.

What are some of the things we may look for in the marketing of fruits and vegetables that can be calculated to improve the lot of our growers? How may these practices affect us as technical workers? Will the retail market of tomorrow be the large-volume, self-service, pre-packaged kind? Will the orange and potato mesh-bag idea be extended to other consumer units? Are our buyers, the housewives, going to be more exacting and choosy about the appearance, packaging, quality, and easy-to-prepare features of the products offered her at the retail markets? Will she require that all trimming be done before she buys the products? And if the "garbage" is thus excluded from the display bins, will the trimming and the packaging be done on the farm or at the retail store, or will it be done at the wholesale market?

Consumer packaging, of course, in one form or another has been here for a long time for berries, mushrooms, cherries, and more recently for potatoes and oranges in bags and tomatoes in cartons. Much investigation has been under way in various parts of the country with consumer packaging. Results in general have been favorable, but how far are we going with the idea? What crops of the South will lend themselves readily to consumer packaging? Do the advantages claimed for the practice actually make it worth the extra expense and trouble? Another question is, what problems in connection with the prospective consumer-packaging should we Southern workers be interested in solving? What products may be most affected? How about varieties? Would the volume of sales of some products be increased by consumer packaging? The orange people, "Idaho Baking" potato people, and the pecan people think so. Could not the same idea be successfully applied to sweetpotatoes or peaches or tomatoes or other crops we grow in the South? Finally, are we working closely enough with organizations representing retailer interests?

Next, with respect to marketing, how about the prospective effects of air transportation? You have no doubt seen in papers and popular magazines headlines like these:

> "Fruit in Memphis from Tropics only 12 hours Old"
> "What Will Air Transport Do for the Grower?"
> "Vegetables by Air"
> "Cargoliner Suggests New Ideas in Transportation and Packaging"
> "Asparagus Takes to the Air"
> "Standards for Airborne Produce"
> "Tomato Plants by Air"
> "First Sweet Corn by Air"
> "Sweets Go to Chicago by Air"

These, and other headlines which could be cited, point up the recent interest in air transportation of perishable products. There is little wonder that this is true with thousands of war trained pilots and other air personnel available. The Memphis headline referred to a 1944 shipment of breadfruit, bananas, coffee, tangerines, and loquat, which left Guatemala City at 11 a. m. and arrived at Memphis at 7:45 p. m. It was delivered at Detroit at 9:50 a. m. the next day, a distance of 2153 miles in 16 hours.

Before the war the U. S. Department of Agriculture cooperated with an air line in some test shipments of flowers, fruits, and vegetables from the West Coast to the East Coast. Results showed varying degrees of success depending upon the product involved.

Last spring tomato plants were pulled in South Georgia one day and were delivered to Ohio growers' fields the next day. Last spring and summer asparagus was shipped by air from California to the Eastern markets and it was on the tables the next day. On November 1, 1945 the first "reefer" plane in history, a fully refrigerated cargoliner of

United Air Lines, a twin-engined Douglas DC-3, equipped with large insulated containers each accommodating about 1,600 pounds, left California with almost a full load of fruits, vegetables, flowers, and emergency serum. At Salt Lake City celery was placed aboard and freshly cut carnations were loaded at Denver. Dry ice was used as the refrigerant in the containers, and the temperatures were held fairly constant. The products were at New York the next day. I quote from a report by Mr. C. P. Graddick of United Air Lines: "By the use of refrigerated pit containers the cabin of a cargoliner can be either fully or partially refrigerated; different temperatures can be provided for different commodities; heat as well as cold can be provided to obtain virtually any desired temperature; and a container can be removed easily from a plane for ground transfer without danger that its contents will suffer from outside temperatures.

"The new method eliminates the need for heavy containers and ice in the shipment of certain commodities. Packaging engineers are alert to the needs of creating new packaging methods for airborne perishables. Lightweight corrugated fiberboard shipping containers were used for these refrigerated plane shipments, providing necessary strength and making possible maximum stowage.

"We have conducted many experiments in moving perishables by air. These have shown us that some commodities need close control of temperature, while all perishables must be protected against excessive heat and cold. The insulated containers we are now experimenting with may well be the answer."

You may be familiar with the 1944 tests by T. W. A., Wayne University of Detroit, and the A & P Tea Company. Reporting these tests some time ago, Mr. J. P. Blount of the air lines had this to say: "We have every reason to believe that air transport can only prove its worth through delivering a superior product. If we don't deliver a superior product, it is hard to justify using a more expensive means of transportation. Shippers and receivers within the next year or two will exhaust the mere publicity value of their pioneering efforts with planeload shipments of fresh produce. As no permanent business can be built on novelty, we must scrupulously avoid being misled by the enthusiasm and publicity surrounding these initial planeloads. We must search out and appraise the real benefits."

He reported that approximately 50 per cent of the airborne lettuce brought about 5 cents more per head, but including all economics involved, this meant only a 6½-cent return per ton-mile. This, according to the air lines official, is insufficient.

To quote Mr. Blount further: "Our research leads us to believe if there is a real improvement in quality, taste, appearance, or nutrition which might justify 50 per cent of the customers paying 5 cents extra on lettuce, then about 1 to 1½ per cent would pay 20 cents extra, which more nearly represents the premium that must be obtained in order to cover the actual increased transportation cost by air with present equipment."

Eastern Air Lines representatives at Atlanta are very much interested in air shipment of produce and some of you are familiar with this work. Mr. T. M. Breeden of Eastern Air Lines recently summed up his opinion on how to make air shipping profitable as follows:

1. Pick out the products that have higher values and do not carry too well.
2. Ship only the choicest fruits, berries or vegetables that have been nature-ripened to perfection.
3. Prepare and pack the products so the consumer has only to open a package and put it on to cook without having to wash off field dust, remove husks, tops, etc. In other words, don't pay for shipping garbage. And finally, develop a consumer package, indicating the product within is air-shipped.

Research by the Bureau of Agricultural Economics, the Edward S. Evans Transportation Research, and various air lines indicates that if air-cargo rates of less than 10 cents per ton-mile should be offered fruit and vegetable shippers, about one-third of the 5 billion ton-miles of fruits and vegetables originating from the winter garden areas probably would move by air cargo. Some of this study was with the air shipment of strawberries and tomatoes from Florida to Detroit. A published report says: "This analysis indicates an air transportation charge of 11.3 cents per quart of strawberries from the Lakeland, Florida area and 8 cents per pound of tomatoes from the Miami area to Detroit. Comparison with charges by competing transportation methods shows that air transportation charges are about 6½ cents higher than rail or truck shipments and 6 cents above rail express per quart of strawberries, and about 6 cents higher per pound of tomatoes. Savings in containers and ripening costs gained by air transportation of tomatoes are about equal to the additional cost. For strawberries the savings in container costs would reduce the additional cost per quart to 5 cents. This would represent a premium paid for what is expected to be a superior quality product."

What do these studies mean to us? Will air transport of our southern crops develop to where it will be the "rule" rather than the "exception"? Will consumers pay the indicated extra charges in order to have the supposedly higher quality? Will it mean that we will sell more products? Will we be able to meet the requirements indicated by these few cited experiments? Will our variety picture change with development of air shipping? We should do well to think thoroughly through these and other questions about this matter of air shipping of horticultural products.

The third group of problems pertains to horticultural education. I have been asking myself and my colleagues questions about the subject for several years. I have wondered whether enough instruction in the various phases of horticulture was being given in our southern institutions. Have we been giving the right kind of instruction? Have we been giving the students enough of what I like to call "an appreciation for" horticulture? How important is horticulture in the life of the average individual? Have we impressed our students with this importance? How about instruction on the relative economic values of horticultural enterprises as compared to others on southern farms? In choosing staff members for instructional assignments, it is my opinion that we should consider more carefully their qualifications for teaching. Amount of training, degrees, and published works do not necessarily always indicate that an individual will be a successful instructor. What are the qualifications of a good teacher? Do we sufficiently recognize the good teacher, or do we take the good teacher too much for granted? In the past we have placed much emphasis on the "know-how" of good research. Are we placing sufficient emphasis on the "know-how" of good teaching?

I recently asked the department of horticulture in each of 12 other southern states to write me about the number of graduates in horticulture which they had in a typical pre-war year and then how many during the 4-year war period. I also asked them whether they thought their institution would see an increased interest in or demand for horticultural courses in the post-war years.

Of the eight institutions from which I have the data, two do not graduate majors in horticulture. Four of the eight are now offering work for students wishing to take the master's degree in horticulture. One reported 16 graduates in 1939, another five that year; others reported one, four, five, and six graduates in 1940, a typical pre-war year. Another state reported a pre-war average of about eight graduates per year. During the years 1943 to 1945 inclusive there were, of course, few graduates in any field of agriculture, because students were in the military services, but horticulture held its usual proportion of graduates.

There is certainly a dire need of more people who are trained for horticultural work, not alone in the educational or technical fields, but also for operating the necessary nurseries, orchards, truck farms, flower shops, greenhouses, and many other commercial enterprises which serve the South. People who make their living by growing and selling horticultural products need additional trained personnel. Institutions in the South need additional trained personnel for teaching, research, and extension. Remember, we have lost about 5 years in training personnel.

In regard to the indicated demand for horticultural courses in the next few years, most of the institutions heard from reported an already substantially increased interest in these subjects. In Mississippi there is a greatly increased interest particularly in commercial ornamental enterprises. Thousands of dollars worth of ornamental plants are shipped into the state annually from northern establishments. The State Florists and Nurserymen's Association has become aroused about this situation, but it is claimed that very little expansion of the industry can be made until more training of workers is accomplished. They can barely operate their businesses on the present level with the available skilled workers. This probably exists also in all the other southern states. The Mississippi Association has been so much interested in this problem that it recently sent its Executive Committee to the college for a conference with the department staff and the administrative officials in an effort to get more courses taught and more facilities provided at the institution for adequate training in ornamental horticulture.

I believe the interest among young men in practicing horticulture in the South is definitely on the increase. As more horticultural courses are offered and as better teaching facilities are made available, more students are going to take them. It is up to us to provide the proper training as well as inspiration for the profession.

I have said that most of the problems which we southern horticulturists will be faced with in the post-war period are those related to production, to marketing, or to education. I have pointed out some of the more obvious of these problems with the hope that such a stock-taking effort might provoke serious thought. How can we best solve these problems? One good approach appears to me to be that of a greater cooperative effort. We have done much in this respect already. As you know, southern horticulturists are associated with home economists and nutrition chemists in pioneering efforts at conducting cooperative research in nutrition studies with vegetables. The original so-called "turnip project" was a classical example of what cooperative effort is capable of accomplishing. The collaborating group of horticulturists currently working on sweetpotato research is another example. We cannot have too much of such cooperation. The conferences being held this week between these groups are an encouraging sign. Some comedian has defined a conference as being a group of people who individually can do nothing, but who meet and in a group decide that nothing can be done. That is not the kind of conference in which we are interested. We want that kind which is characterized by expressions of well formed opinions based on actual information, which when pooled from all sources will point toward the solution of our problems; which will develop plans of cooperative action and thus point the way to the best possible result for the expenditure of human effort and funds involved. Too much of these have been wasted in the past by groups working separately in similar areas on similar problems, but doing the work just enough differently that results could not be combined or compared.

What better thing could the members of this society do than agree to waste nothing by unnecessary duplication of effort? Let us resolve to strive for cooperation in all of our efforts to cope with the problems common to southern horticulture. It is up to us to lead; to guide the horticultural thinking in the South; it is our duty and responsibility—and these problems are our challenge.

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